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TRANSACTIONS

OF THE

Illinois State Academy of Science

EIGHTH ANNUAL MEETING

Springfield, Ill., Feb. 19 and 20, 1915

VOLUME VIII

1915

OHIO STATE
UNIVERSITY

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Edited By
A. R. CROOK
1915–1916

OHIO STATE
UNIVERSITY

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OFFICERS AND COMMITTEES FOR 1915-1916

President, U. S. GRANT, Northwestern University, Evanston.
Vice-President, E. W. WASHBURN, University of Illinois, Urbana.
Secretary, A. R. CROOK, State Museum, Springfield.
Treasurer, H. S. PEPOON, Lake View High School, Chicago.

The Council

PRESIDENT, PAST PRESIDENT, VICE-PRESIDENT, SECRETARY, AND TREASURER

Publication Committee

THE PRESIDENT, SECRETARY, AND C. H. SMITH, Editor "School Science," 5517 Cornell Ave., Chicago.

Membership Committee

G. D. FULLER, University of Chicago, Chicago.
E. N. TRANSEAU, State Normal School, Charleston.
W. S. BAYLEY, University of Illinois, Urbana.
L. I. SHAW, Northwestern University, Evanston.
J. S. COMPTON, Eureka College, Eureka.

Legislation Committee

A. R. CROOK, State Museum, Springfield.
WILLIAM BARNES, Decatur.
ALICE J. PATTERSON, Normal.
E. O. JORDAN, University of Chicago, Chicago.
T. L. HANKINSON, State Normal, Charleston.
THOS. E. LYON, 413 S. W. Grand Ave., Springfield.

Calendar Committee

F. R. MOULTON. University of Chicago, Chicago.
A. R. CROOK, State Museum, Springfield.
C. G. HOPKINS, University of Illinois, Urbana.
E. J. TOWNSEND, University of Illinois, Urbana.
T. C. CHAMBERLIN, University of Chicago, Chicago.

Ecological Survey Committee

S. A. FORBES, State Entomologist, Urbana.
H. C. COWLES, University of Chicago, Chicago.
T. L. HANKINSON, State Normal School, Charleston.
V. E. SHELFORD, University of Illinois, Urbana.
F. C. BAKER, Academy of Science, Chicago.
H. S. PEPOON, Lake View High School, Chicago.
G. D. FULLER, University of Chicago, Chicago.

Secondary Science Committee

OTIS W. CALDWELL, University of Chicago.
WORALLO WHITNEY, Bowen High School, Chicago.

PAST OFFICERS OF THE ACADEMY

1908

President, T. C. CHAMBERLIN, University of Chicago.
Vice-President, HENRY CREW, Northwestern University.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1909

President, S. A. FORBES, University of Illinois.
Vice President, JOHN M. COULTER, University of Chicago.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1910

President, JOHN M. COULTER, University of Chicago.
Vice-President, R. O. GRAHAM, Illinois Wesleyan University.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1911

President, W. A. NOYES, University of Illinois.
Vice-President, J. C. UDDEN, University of Texas.
Secretary, FRANK C. BAKER, Chicago Academy of Science.
Treasurer, J. C. HESSLER, James Millikin University.

1912

President, HENRY CREW, Northwestern University.
Vice-President, A. R. CROOK, State Museum of Natural History.
Secretary, OTIS W. CALDWELL, University of Chicago.
Treasurer, J. C. HESSLER, James Millikin University.

1913

President, FRANK W. DEWOLF, State Geological Survey.
Vice-President, H. S. PEPOON, Lake View High School, Chicago.
Secretary, E. N. TRANSEAU, Eastern Illinois Normal School.
Treasurer, J. C. HESSLER, James Millikin University.

1914

President, A. R. CROOK, State Museum, Springfield.
Vice-President, U. S. GRANT, Northwestern University, Evanston.
Secretary, EDGAR N. TRANSEAU, Eastern State Normal School, Charleston.
Treasurer, JOHN C. HESSLER, James Millikin University, Decatur.

Minutes of the Eighth Annual Meeting

SPRINGFIELD, ILLINOIS, FEBRUARY 19 AND 20, 1915

The meeting was called to order in the lecture room of the State Museum at 2 p. m., Friday, by President A. R. Crook. Mr. Finley Bell of the State Legislature Reference Bureau gave an address of welcome on behalf of the State Government in the absence of the Governor and also extended a cordial invitation to the members of the Academy to visit the newly established Reference Bureau.

The President replied, thanking the speaker for the cordiality of the reception and expressing the interest of the Academy in the welfare of all branches of the State Government.

The reports of the Secretary and the Treasurer were read. (See pages 11 and 13.)

The Calendar Committee, through Dr. A. R. Crook, reported progress in securing the attention of other organizations of scientific and business men in this country and abroad, to the need of an improved calendar. It was moved and passed that the Calendar and the Legislative Committee be continued. The President then appointed the Auditing, Nominating and Resolutions Committees.

The Symposium on Colloids was then presented and a paper read by Dr. Don W. Deal.

At 6 o'clock a banquet given in honor of the Academy by the Springfield Commercial Association was enjoyed at the Leland Hotel. Ex-Governor W. A. Northcott acted as toastmaster. Senator Keller gave an address of welcome to which Professor John M. Coulter responded. One of the features of the banquet was the excellent singing by the Chorus of the Commercial Association.

At 8 o'clock the Academy joined an audience of over two thousand citizens of Springfield at the Armory, to hear an address by Dr. A. L. Day, Director of the Carnegie Geophysical Laboratory, of Washington, D. C., on "Volcanic Emanations." The lecture was illustrated by a remarkable series of photographs of volcanic phenomena displayed by the volcanoes of Hawaii.

At 9 a. m., Saturday, the Academy assembled at the Capitol Building. Two sections were organized; one including the papers in Botany, Bacteriology and Chemistry, under the chairmanship of Professor E. W. Washburn, and one including the papers in Zoology, Entomology and Geology, under the chairmanship of Professor H. B. Ward. In the former section thirteen papers, in the last ten papers, were presented.

The Saturday luncheon was served in the State Museum by a committee of ladies acting for the Springfield members of the Academy and the State Museum.

At 2 p. m. the Academy reassembled in the Senate Chamber. President Crook delivered an address on "The Relation of Academies of Science to the State." Ex-Governor Northcott gave an address on "The Philosophy of Science."

By way of a report for the Committee on Secondary Science, Professor J. C. Hessler read a paper on the "Relation of Chemistry Courses to the High School Domestic Science and Agriculture." On motion of Professor Noyes the Secretary was ordered to forward this paper to "Science" for publication.

Professor S. A. Forbes presented a report for the committee on Ecological Survey.

Dr. H. S. Pepoon offered resolutions concerning a home for the State Academy and the State Museum which were unanimously adopted.

Professor W. S. Bayley notified the Academy of the following proposed changes in the constitution which will be brought up at the next session:

To amend Art. III of the constitution (1) *by striking out the words "corresponding members" and "honorary members" from the first paragraph, and by inserting the word "and" before "life members,"* (2) *by striking out paragraphs* 4 *and* 6 *relating to corresponding members and honorary members.*

It is also recommended that the Executive Committee be instructed to remit the initiation fee for any of the present corresponding and honorary members who may be elected to active membership.

Miss Alice Patterson moved that an effort be made to affect county organizations for the setting aside of plats of natural vegetation in each county, to preserve for future generations some of our native fauna and flora which are now threatened with extinction. The financing of these projects is to be done by securing both local and State aid. On action the matter was referred to the Legislative Committee.

The Auditing Committee, consisting of Professor J. L. Pricer, Professor J. S. Compton and Mr. Neil Lutes, reported that the accounts had been carefully examined and found correct.

The Nominating Committee, Professor Edward Bartow, Chairman, made the following nominations for officers for the ensuing year:

President, Professor U. S. Grant, Northwestern University.

Vice President, Professor E. W. Washburn, University of Illinois.

Secretary, Dr. A. R. Crook, State Museum, Springfield.

Treasurer, Dr. H. S. Pepoon, Lake View High School, Chicago.

Member Publication Committee, Mr. C. H. Smith, Editor School Science, Chicago.

On motion the Secretary cast the ballot, and they were declared elected.

Mr. Frank W. DeWolf, speaking for the members from Urbana, invited the Academy to hold its 1916 meeting at the University of Illinois. The Academy voted to accept this invitation.

On motion the Academy adjourned.

E. N. TRANSEAU, Secretary.

REPORT OF THE SECRETARY

1913-1914

The seventh annual meeting of the Illinois Academy of Science was held at Northwestern University, Evanston, February 20 and 21, 1914, under the presidency of Mr. Frank W. DeWolf, Director of the State Geological Survey.

The program of Friday afternoon included the President's Address on "Recent Investigations of the Mineral Resources of the Country"; an address on "Earth Tides" by Professor A. A. Michelson; an account of the "International Phytogeographical Excursion" by Professor Henry C. Cowles, and an address on "Recent Theories of Fertilization and Parthenogenesis" by Professor Frank R. Lillie.

At 6 p. m. the members enjoyed a banquet in the University Gymnasium as the guests of the University. President Abram W. Harris made a short address of welcome.

Following the banquet the Northwestern Chapter of Sigma Xi gave an informal reception in the Physical Laboratory. A feature of this occasion which was enjoyed by all was the exhibit and demonstration of many new pieces of physical apparatus.

On the Saturday morning following the reports of the various committees the Academy listened to eleven papers by members.

The officers elected for the following year were:

President, Dr. A. R. Crook, State Museum, Springfield.

Vice President, Professor U. S. Grant, Northwestern University, Evanston.

Secretary, Dr. E. N. Transeau, State Normal School, Charleston.

Treasurer, Professor J. C. Hessler, Millikin University, Decatur.

Member Publication Committee, Professor S. A. Forbes, Urbana.

A meeting of the Council was held at Decatur, June 20, 1915. The program for this meeting, and the possibility of publication of the Transactions were discussed. It was decided that in view of the reduction of our income through the cutting off of the appropriation from the State, that the publication of our proceedings should be held over until 1915. The papers read at the Evanston meeting are all in the hands of the Secretary and the manuscript is ready for the printer. Mr. M. I. Reiffel, Chicago, and Professor F. L. Stevens, Urbana, were elected to membership, subject to the approval of the Academy.

The Academy now has an enrollment of three hundred and twelve members, well distributed over the state. Efforts to secure the interest of high school teachers and others in the work of the Academy have been continued by means of letters and circulars. Respectfully submitted,

E. N. TRANSEAU, Secretary.

REPORT OF THE TREASURER

February 19, 1915.

RECEIPTS

Balance on hand February 20, 1914	$235.91
Received from membership fees	273.00
Received from initiation fees	19.00
Received from exchange on checks	.25
Total receipts	$528.16

EXPENDITURES

To the Charleston Courier, printing	$239.75
To the Charleston Plaindealer, printing	17.25
To E. N. Transeau, Secretary	52.92
To the West Paper Co., envelopes	.60
To John C. Hessler, Treasurer	11.48
To Herald Printing & Stationery Co., printing	3.35
To the Barnes-Crosby Co., Chicago	1.07
Total expenditures	$328.42

SUMMARY

Total receipts Feb. 20, 1914, to Feb. 19, 1915	$528.16
Total expeditures for same period	328.42
Balance on hand Feb. 19, 1915	$199.74

JOHN C. HESSLER, Treasurer.

RESOLUTIONS ADOPTED CONCERNING THE STATE MUSEUM AND STATE ACADEMY

Whereas, The State Museum of Natural History contains many collections from the State of Illinois and elsewhere invaluable to the scientific interests of the State; and

Whereas, These collections are housed in wholly inadequate space, and displayed in an unsuitable and antiquated manner; and

Whereas, The State Academy of Science, by its by-laws, meets at intervals in Springfield, and by its work and sympathies necessarily affiliates with the State Museum; and

Whereas, The State of Illinois contemplates the erection at some near date of a commodious structure to house important state departments not now well provided for:

Resolved, By the Illinois State Academy of Science that the Legislature of the State of Illinois be and is earnestly requested to make suitable provisions for the State Museum in the new structure and also provide a definite Springfield home for the State Academy of Science.

H. S. Pepoon, Chairman.

REPORT OF THE RESOLUTIONS COMMITTEE

The Illinois Academy of Science desires to record its deep appreciation of the splendid provision made for its annual meeting at Springfield, which has been one of the most successful it has ever had. The City of Springfield has extended so cordial a welcome and has provided for the Academy so bountifully that the occasion will remain a memorable one in the annals of the organization.

First and foremost, the thanks of the Academy are due to the trustees and staff of the State Museum, each one of whom has contributed by every means in his power to the comfort and convenience of the members present.

To the local committee and to the chairman and workers on the various sub-committees the Academy is indebted for the foresight that has met every need in so satisfactory a manner and has enabled the organization to carry out its program rapidly and effectively.

To Governor Dunne, ex-Governor Northcott, and to many others who rendered special services of great value the Academy desires to express its appreciation for their willingness to add to an already heavily loaded program of duties and to lend material aid in making the Springfield meeting so marked a success.

Finally the Academy feels under lasting obligations to the President and other officers and members of the Springfield Commercial Association, and to the others, especially the singers, who planned and carried out so attractive a social gathering and banquet last evening. The members of the Academy appreciate the opportunity of meeting personally the citizens of Springfield present at the banquet and believe

that such personal contact and exchange of ideas will contribute much to the development and progress of the great State of Illinois.

H. B. WARD, Chairman.

REPORT OF THE COMMITTEE ON AN ECOLOGICAL SURVEY OF THE STATE

To the Illinois Academy of Science:

Your Committee on an Ecological Survey reports progress as follows:

In Dr. Cowles's department an interesting ecological study has been made by Mr. F. T. Ullrich on the types of vegetation in a ravine near Chicago as affected by differences of evaporation in the air and different ratios of soil moisture in different parts of the ravine. The aerial evaporation was determined for seventeen stations by the use of a Livingston atmometer, read weekly from July 5 to October 18 (one hundred and twelve days), and the soil moistures were ascertained by the weighing and drying of samples of soil collected weekly from three of these stations at depths of seven and a half centimeters and fifteen centimeters. Mr. Ullrich's paper will be published in the Bulletin of the Illinois State Laboratory of Natural History.

Dr. Shelford has studied the effect upon fishes of the wastes and liquors from the manufacture of illuminating gas, with a view to learning the effect upon fishes and other useful aquatic animals of a contamination of streams. The interesting and important conclusion was reached that fishes, on encountering natural substances commonly found in water as the result of decomposition of organic matter, nearly always react in a way to protect themselves against such contaminations, and thus to preserve the species; but in the case of artificial gas wastes, fishes usually swim into them without turning back in the usual fashion, as if unaware of their noxious quality, even though death may result within a few minutes. This was found true of the gas liquor and also of the principal dissolved gases taken separately. The gas wastes contained many compounds detrimental to fishes, any one of which is dangerous in itself, and no less so in combination with others.

A careful study of the chemical relations of fishes has been made by Mr. M. M. Wells, who has found that Illinois fresh-water fishes are very sensitive to acid and alkaline conditions of the water. Fishes avoid alkaline and neutral waters, and select those slightly acid with carbon dioxide, but avoid waters containing large amounts of acid — conditions particularly detrimental to the young. Mr. Wells has also found that fishes are least resistant to detrimental conditions during the breeding season, some species dying at once when taken from water at this time.

Dr. H. S. Pepoon has been completing his flora of the Chicago area, now practically ready for the printer, and has been working up also his plant collections from the driftless area in northwestern Illinois, in which he has found many new forms and extensions of plant localities. His Jo Daviess county list now contains nearly a thousand species, several of which are not found in Gray's Manual.

Mr. F. C. Baker has continued his studies of the ecological features of the basin of the glacial Lake Michigan. Shallow-water and deep-water faunas have been found in the new Calumet-Sag Channel, now under construction. A section thirty feet deep near Worth shows the same fauna which was observed by Baker in the North Shore Channel at Bowmanville, as reported in Volume IV of the Academy Transactions. A Unio species especially charactceristic, *Unio crassideus,* was present in great numbers. Mr. Baker finds evidence that a rich Unio fauna migrated up the Des Plaines during the Calumet stage and became well established by the time the water had lowered to the Toleston level. The fauna of the Algonquin and Nipissing stations is large and varied, the species represented indicating the fluctuations in depth as the level of the water rose and fell. A report covering the life of the Pleistocene, as recorded in both post-glacial and interglacial deposits, is now nearly finished and ready for publication.

The ecological work of the Illinois State Laboratory of Natural History has been substantially in continuance and verification of the Illinois River work of 1914, special attention being paid, however, to collections of the stomachs of fishes for an elaborate study of the food of different species in different situations. Materials were also collected for food studies of aquatic invertebrates living on the bottom. Many dredge collections were obtained from the Illinois River and connected lakes; and a special biological examination of Fox

River was made from Aurora to Elgin, with extensions to neighboring points. Respectfully submitted,

STEPHEN A. FORBES.

REPORT ON THE RELATION OF CHEMISTRY COURSES TO APPLIED SCIENCES OF THE MODERN HIGH SCHOOL

The purpose of the committee that I represent is, I suppose, to bring to the amateur and professional specialists who make up the greater part of the Academy the "new word" regarding high school science. The Academy first gave official recognition to the high schools a few years ago, when it appointed a committee to report upon the organization of the sciences in the high schools and upon the correlation that was being attempted between the pure and applied sciences. The committee's report was of a comprehensive character, and was presented to the 1912 meeting by the chairman, Mr. Worrallo Whitney. Last year the committee's report was upon general science in the high school. This year the chairman has asked me to speak briefly upon chemistry in its relation to the newer, special courses, such as agriculture and domestic science. The situation of physics is so closely related to that of chemistry that I shall consider both more or less together, without making any great distinction between them.

How is chemistry teaching being affected by the presence of agriculture and domestic science in the curriculum? If we are truthful we shall admit that the effect varies all the way from a maximum to zero. At one extreme are the schools, happily few, in which the chemistry that does not lead to applied science is not tolerated at all; at the other extreme sits, in serenity, the classical chemist, who has worked out his scheme of logic from the chemical point of view, and proposes to teach that and nothing else, though the heavens fall. Between these extremes there is the great body of chemistry teachers, men and women who are seeking to teach the fundamental things of the pure science, and yet are willing and ready to draw their illustrations from the newer materials of the applied science.

What about agriculture and domestic science as the exclusive sciences of the high schools? Unless I am greatly mistaken, the calm afterview has brought, or will soon bring,

a realization of the limitations that are necessarily inherent in the teaching of special sciences to young people. Experience is teaching us that the study of scientific agriculture and household economics cannot be made particularly stimulating or permanently helpful unless there is a basis of the physical sciences, taught as such, and not as mere illustrations of some special science. This means, of course, that the many children who leave school early in the course cannot get technical agriculture and domestic science. But this cannot be helped. The problem is the old one of the development of courses. We want all children to have American history, but in the nature of things little history can be given, even in a simple way, until the child is ready for it. How little that is, all of us are too painfully aware. We want all college students to have some philosophy, but we cannot give it with any effect before history, science and mathematics have had an opportunity to do their enlarging work. So it is with agriculture and domestic science, subjects which, more than other studies, bring about the application of science to daily life. Each generation gives into the hand of the young agriculturist the use and the care of his soil. The schools cannot help him much if they do not let him see the science upon which permanent agriculture rests, but teach him only the jargon of a trade. Likewise with domestic science. We cannot impart a much higher conception of housekeeping and homemaking if we do not give the deeper, fundamental view that comes from a speaking acquaintance, at least, with chemistry and physics, and I may add, with biology.

This brings us to a consideration of the position of physics and chemistry in the high school course. As you know, these sciences are usually taught in the last two years. As a result, the agriculture and domestic science courses that come in the earlier years do not have any foundational work in the physical science. Evidently, then, the school must either put chemistry and physics into the first years of the high school, or it must offer, in these first years, an elementary physical science that shall serve as a basis for agriculture and domestic science, and for biology as well. This report of mine may be more of a prophecy than a chronicle, and a statement of what should be rather than of what is, but it seems to me that the conditions of modern life will compel us to put two kinds of physico-chemical science into the high school. One of these will be a course that comes early, is elementary, dispenses with theory and equation, and aims to open the student's eyes, to give him a vocabulary, and to set him into connection with

the world about him. If the "six and six" plan of division of the high school and the grammar school comes into vogue, this elementary course may go into the eighth year instead of the ninth. This course will not be closely correlated with agriculture and domestic science. The other course in chemistry or physics will be the formal course of the third or fourth high school year. This need not be a more difficult course than the present one, but it should be far richer. It should give not only the logical and quantitative concepts of the master minds of chemical and physical science, but should be correlated with the real agricultural and domestic science of the upper years of the course.

It is a curious fact that the order of the science studies of high schools has changed little, fundamentally, for a generation, and this in spite of the fact that the period named has witnessed the introduction of the laboratory method into secondary instruction. Thus, thirty years ago the science course in the Chicago high schools was, I believe, about as follows:

First Year—Physical Geography and Physiology, one-half year each.

Second Year—Zoology and Botany, one-half year each.

Third Year—Chemistry, one year; Physics, one year.

Fourth Year—Geology and Astronomy, one-half year each.

At the present time the standard course in the same schools is essentially the same, the only prominent change being in the omission of geology and astronomy from the fourth year, and the putting of physics into their place. There is certainly one thing to be said in favor of this older course, even though it offered no laboratory work: Every one going through the high school took the *five* years of science work, whereas today far too many avoid the greater part of the course altogether.

One question more will be suggested in this report: What kind of a teacher is needed for the elementary physical science of the early years of the high school and for the course correlated with agriculture and domestic science in the later years? For, be it known, you can correlate the pure and the applied sciences far more easily than you can "correlate" the teacher. The principal of one of the largest high schools of the State told me not long ago that he had given up hope of getting from his chemistry teachers a proper chemistry course for the domestic science girls of the school. The teachers were well prepared for their work, but they simply could not adapt

their knowledge to the needs of the domestic science students. What he was seeking was a woman who had a thorough knowledge of chemistry and also of domestic science, and who had made, as a part of her own education, the needed correlation between the two. This brings me to the fundamental fact in the high school situation in Illinois, as all roads lead to Rome, viz., that the public is, as yet, more willing to put up buildings, and to equip laboratories, miniature experiment stations, and domestic science kitchens than it is to demand and to pay for competent teaching. Is it out of place for me to suggest to the members of the Academy that each of them can do no greater service to the cause of science in this State than to study and to seek to improve, if possible, the high school science instruction in his own community?

JOHN C. HESSLER,
Chairman Committee on High School Science.

MEMBERS ELECTED AT THE 1915 MEETING

Miss Frances D. Abbot, 523 S. Glenwood, Springfield. (Botany.)
Mr. S. O. Andros, Urbana. (Geology).
Dr. C. M. Bowcock, Springfield. (Medicine).
Dr. Jessie Y. Cann, 1010-2 California St., Urbana. (Chemistry.)
Mr. H. P. Corson, Urbana. (Chemistry.)
Dr. William Crocker, University of Chicago, Chicago. (Botany).
Mr. W. P. Flint, 1231 W. Edwards, Springfield. (Entomology).
Miss Glen Griggs, 223 S. Madison, Clinton. (Biology).
Professor Wm. H. Haas, Northwestern University, Evanston. (Geography).
Dr. Charles F. Harmon, 318 S. 6th, Springfield. (Medicine).
Mr. M. E. Hinds, M.S., 116 Chem. Bldg., Urbana. (Bacteriology).
A. W. Homberger, Ph.D., Bloomington (Chemistry).
Geo. T. Johnson, 623 Black Ave., Springfield. (Astronomy).
Mr. Fred S. Kay, State Geological Survey, Urbana. (Geology).
Dr. George N. Kreider, 522 Capitol Ave., Springfield. (Surgery).
Mr. George Langford, Supt. Steel Mills, Joliet. (Paleontology).
Dr. Frances Lowater, Rockford College, Rockford. (Physics).
Dr. I. W. Metz, S. Grand Ave., Springfield. (Medicine).
Mr. F. W. Mohiwan, M.S., 116 Chem. Bldg., Urbana. (Chemistry).
Mr. Norman F. Nelson, 1020 N. Main St., Rockford. (Botany).
Mr. H. L. Olin, University of Illinois, Urbana. (Chemistry.)
Geo. Pasfield, M.D., Pasfield and Jackson, Springfield. (Medicine).
J. E. Pogue, Ph.D., Evanston. (Mineralogy).
Mr. W. J. Risley, B.S., Millikin University, Decatur. (Mathematics).
Mr. C. H. Robinson, Normal. (Archaeology).
Mr. Clarence N. Ross, University of Illinois, Urbana. (Geology).

Mr. Henry F. Schneider, 1825 S. Spring, Springfield. (Geology.)
A. R. Trapp, M.D., Springfield. (Med. Diag..)
Charles H. Shammel, Ph.D., 535 Black Ave., Springfield. (Geology).
H. C. P. Weber, Ph.D., University of Illinois, Urbana. (Chemistry).
Professor F. L. Stevens, University of Illinois, Urbana. (Botany).
Mr. M. I. Reiffel, Chicago. (Botany).
Illinois State Library, Springfield.
Miss Mildred Weigley, 419 College Ave., DeKalb. (Household Science).
Miss Eva Southworth, 419 College Ave., DeKalb. (Geography).
Robert C. Lanphier, Sangamon Electric Co., Springfield. (Electrical Engineering.)

Addresses

ADDRESS OF WELCOME

Senator Kent E. Keller in welcoming the Academy to Springfield called attention to the progress of the State from the time of the early settlers to the present and showed how this progress was the result of great natural resources utilized by inquiring, thoughtful and energetic men. The spirit of inquiry which is the scientific spirit is the greatest element in all progress. Men of science are the State's chief asset.

RESPONSE

JOHN M. COULTER

In behalf of the State Academy, I wish to express our appreciation of the hospitality of the Commercial Club, and also of the greetings extended to us by the official representatives of the State.

The three groups represented here tonight are significant. They are the State, business, and science, each in its own way serving this great commonwealth.

The mission of science, as represented by this Academy, is twofold. In the first place, it works through its teachers in developing the scientific attitude of mind in coming citizens. This attitude is fundamental in a self-governing people, for it is one that demands the facts; that knows how to recognize facts; and that distinguishes between demagoguery and real service.

As this spirit becomes dominant, the State will advance from politics from the standpoint of selfish interest, to politics from the standpoint of public service. In the second place, science works for the State through its investigators, whose researches not only uncover our resources, but also suggest the best way of developing them. In a great agricultural State, for example, nothing is more fundamental than the modern work of investigation in plant-breeding, which bids fair to revolutionize our methods and enormously multiply our

products. This combined service in improving citizenship and in increasing output, should be encouraged in every possible way.

The mission of business needs no explanation in this presence. It lays hold of our material opportunities and makes the most of them. In developing its own strength, it is in a position to strengthen everything that contributes to the general welfare. It should remember, however, that it is undergirded by science; that it is the results of investigators that bring the suggestions to practical men, who transform them into the terms of public service.

The mission of the State is to conserve and stimulate all those agencies which make for strength and progress. It is right that legitimate business shall be safeguarded and encouraged. It is fundamental that science shall be fostered, both in its teaching phase and in its research phase, for it makes for intelligent citizenship and material progress; and there is no agency through which science in the state can be stimulated so effectively as through the State Academy. It is here that teachers and investigators meet, and from such meetings teachers return to do better teaching, and investigators to do better investigating. To maintain such an agency, therefore, is one of the great opportunities of the state, for no investment will bring larger returns.

THE PHILOSOPHY OF SCIENCE

Ex-Governor W. A. Northcott
Springfield, Ill.

Things must be thought out before they are wrought out. Science is the thought of things and art is the doing of things. The architect first thinks out the great building that the artisan afterwards creates. The sculptor first sees in the rough marble the beautiful creation he afterwards gives to the world. The battle is first thought out by the general before it is fought out by the soldiers. The long-headed man, before the beginning of a great undertaking, in his mind cancels all difficulties and in the performance there is no wasted effort. Science is the triumph of mind over matter.

Science has made more rapid strides in the last one hundred years than in all the world's preceding history. "Close behind the worshipers of knowledge have followed the ma-

gicians of today; chemists, engineers and electricians. At their command the spirits of air, water, earth and fire have been made to do man's every bidding. They propel his steamships, railway cars, and mighty engines; they make his garments; they build his houses; they illuminate his cities; they harvest his crops. For him they make ice in the tropics or grow oranges amid snow. For him they fan a heated atmosphere into cooling breezes or banish icy winds. They flash his news around the globe; they carry the sound of his voice for thousands of miles, or preserve it after he is dead. Verily the fairies and genii of old did not so much for Solomon in all his glory."

Science has followed closely on the dreams of the poet and made them realities. Many years ago Tennyson said:

"Here about the beach I wander'd, nourishing a youth sublime
With the fairy tales of science, and the long result of Time;
When the centuries behind me like a fruitful land reposed;
When I clung to all the present for the promise that it closed.

When I dipt into the future far as human eye could see;
Saw the Vision of the world, and all the wonder that would be.—"

"Saw the heavens fill with commerce, argosies of magic sails,
Pilots of the purple twilight, dropping down with costly bales;
Heard the heavens fill with shouting, and there rain'd a ghostly dew,
From the nations' airy navies grappling in the central blue;

Far along the world-wide whisper of the southwind rushing warm,
With the standards of the peoples plunging thro' the thunder-storm;

Till the war-drum throbb'd no longer, and the battle-flags were furl'd
In the Parliament of man, the Federation of the world.

There the common sense of most shall hold a fretful realm in awe,
And the kindly earth shall slumber, lapt in universal law."

The dream of Tennyson is a reality of today and many European cities now with dread see "the nation's airy navies grappling in the central blue."

The submarine that can go a thousand miles under the water and with deadly blow destroy the strongest warships; the armored automobile; the cannon that will carry twenty-five miles, are all creatures of the giant—science that has come to rule the material world.

Said one Irishman to another: "Mike, I see they are sending telegrams now without any poles or any wires." "Yes," replied Pat, "and pretty soon we will be able to travel without leaving home." This is about true today. Seated in the halls of our home town, the moving pictures take us to the most extended corner of the globe and we become conversant with the

lives among the antipodes. The phonograph preserves the voice, and the picture galleries of ancestors in the future will not only give the face but the movements and the voice, and man will become practically immortal.

There is an account of a man employed in the Patent Office who wrote to a friend he was going to resign because it was only a temporary job. That the patents would all soon be exhausted and there would be no more business for the department. This letter was written in 1837, and since that time millions of inventions have been patented and there are millions more to come. This man made a bad guess.

It is impossible here to review all of the great strides made by science in the last hundred years and we pause to ask with John Ruskin, "Does the making of costly fabrics and the traveling of many miles an hour make us any wiser or happier?" Do these great scientific inventions make us get anything out of nature's establishment any cheaper? If we want to be strong we have to work. If we want to be wise we have to read and think. If you want to be happy you have to love your fellow man. Nature has no bargain counter and there is no loyal road to any place worth going to. The scientific inventions improve the material conditions of mankind but they are not going to cheat nature out of anything. Huxley once said:

"If I understand the matter at all, Science and Art are the obverse and reverse of Nature's medal, the one expressing the eternal order of things in terms of feeling, the other in terms of thought. When men no longer love or hate; when suffering ceases to cause pity and the tale of great deeds causes no thrill, when the lily of the field shall seem no longer more beautifully arrayed than Solomon in all his glory, and the awe has vanished from the snow-capped peak and deep ravine, then and not until then will Science supplant Nature."

We are not going to get any happiness out of this world in any way different from the way in which our fathers did. The science of the mind does not take the place of the heart. An eminent writer states the case very strongly:

"There is the poetry of life itself, more potent than anything in books can be. Nor need one search for it. The sunlight of a dawn slanting through your window; the twittering of birds in the tree-top; the dandelions in the grass; children romping in the park; the wistfulness in the eyes of your own little boy and girl; the sight of two lovers at a trysting place; the quiet happiness and understanding of the old couple at their golden wedding; the friend whom you salute at the street corner; fel-

low-workers content in their daily routine; the soaring lines of the skyscraper or the lonely sycamore; the ceaseless pulsing of the city street or the hush and winter calmness of a country hillside; the farmer among his stock or the sailor in the rigging; the cry of the wind and the swirl of snowflakes; the calm fireside at home and the rustle and leap of its flames; night and the eternal stars—these make the poetry of life, given to all, and transcending all else."

Knowledge is power. It gave liberty to Greece and glory to Rome. Science is knowledge and adds to the power of man. Whether this knowledge is a blessing or a curse, depends upon how it is used. In the hands of a bad man, it makes him only the stronger for evil; in the hands of a good man it makes him stronger for good. In the last analysis it is a question of added power and not necessarily of added good. The steam adds power to the engine, but unless there is an intelligent hand at the throttle it becomes an engine of destruction instead of usefulness. It has been said that the ignorant expert is better than the learned fool, but is not a learned expert better than either? Science in the correct theory proves useless unless applied to correct practice. Good practice on bad theory is just as useless. The ideal condition is the combination of correct theory with correct art and character makes it serve good purposes. Some fear is expressed that science may conflict with the teachings of the Church. On this subject, thirty years ago, Mr. Rice said:

"The Church has learned wisdom. The persecution of Galileo is not likely to be repeated. And Science too has learned something. In all its wealth of discovery, it recognizes more clearly than ever before the fathomless abysses of the unknown and unknowable. It stands with unsandaled feet in the presence of mysteries that transcend human thought. Religion never so tolerant. Science never so reverent. Nearer than ever before seems the time when all souls that are loyal to truth and goodness shall find fellowship in freedom of faith and fellowship of love."

THE PRESIDENT'S ADDRESS—THE RELATION OF ACADEMIES OF SCIENCE TO THE STATE.

A. R. Crook, Springfield, Ill.

The Illinois State Academy is *true to type* as defined in Brittania, which says:

"An academy of science is a society whose object is the cultivation and the promotion of science undertaken for the pure love of these pursuits with no interested motive."

It thus differs from many organizations whose motive is profit of a pecuniary character for the members. In our organization the motive is the promotion of research and the diffusion of scientific knowledge for the advantage of the people of the State.

Membership in the Academy does not convey distinction. Any one of reputable character who is genuinely interested in science is welcomed as a member. Fortunately the most prominent of our men of science are active members of the Academy, but high school boys are welcomed just as cordially—they are the eminent men of science of the future. The Academy is not exclusive or aristocratic. On the contrary, it is genuinely democratic.

As one meets man after man of our membership he finds an interesting company. They may be connected with an educational institution or not. They have usually the charm of individuality. For example, there is Mr. F., one of the most successful collectors of shells in the United States, who has a remarkable collection of snail shells which he has brought together in a search extending from Maine to Oregon and from Arizona to Florida. A few weeks ago the conchologist of the Philadelphia Academy of Science said to me: "Mr. F. has a remarkable faculty of finding the shells in which we are interested. When in the field he seems to go directly to the pile under which the shells are hidden while I wander around in vain."

Another interesting member of the Academy works in a steel mill. A few years ago when his left hand was caught in the cogs of a wheel he had sufficient quickness, strength and courage to throw his arm around a pillar and to hold until his left arm was torn from the body and his life was saved. In spite of this affliction he has done remarkable work in paleontological collecting. Equipped with the kind of hammer dentists use he has carefully and patiently chipped out very delicate fossils. He has one of the most complete collections of mastodon tusks and teeth which I have seen outside of a public museum.

Another interesting member—just to mention one of the many men connected with educational institutions—has the habit of picking up medals! He is the second man in the United States to receive the Copley Medal given by the English government (the first being Benjamin Franklin). A few years ago he received the Nobel Prize for the best contribution in physics—the only Illinoisan thus far to receive this prize. We are hoping that each member of the academy will take his turn at this prize.

What the relationship between the Academy and the State should be can best be determined by comparing past and present practice in this regard and by conceding the services which each may render the other.

Not until recently did I happen to notice that Alexander the Great gave to the Academy of Aristotle at Athens, 800 talents —a large sum of money—and sent men to distant countries to collect plants, animals and oter natural history objects. The result of this was the production of the best natural history of those times.

The first Ptolemy founded the Academy of Alexandria, housed it in a palace, supplied it with instruments, natural history objects and books. Its library of 700,000 volumes was the most famous of antiquity. In its walls studied Euclid, the father of geometry; Archimedes, the mathematician, who invented the spiral screw used to raise the waters of the Nile for irrigation; and Eratosthenes, who studied the elevation of lands, measured the circumference of the earth and pursued other geological and astronomical subjects. For seven hundred years this academy with its library and museum, was the center of learning for all Africa and Europe.

Italy has had many academies. They were supported by such rulers as the Medici, and by Prince Fredrico Cesi, who founded and supported the Academia of Lincei in 1603—the oldest of the Italian academies and the one to which that famous academician, who was the subject of a charming address by one of our presidents, Galileo, belonged.

Every European country in fact has one or more state academies of science. Just to mention a few of the most prominent we may note the English Academy, the Royal Society, which was founded in 1662 by Charles II. Four years later Louis XIV started the French Academy. Thirty-four years later (1700) Frederick I started the Berlin Academy with its libraries, museums, and laboratories. A magnificent new build-

ing was, before the outbreak of the war, being erected for it in Berlin. Twenty-four years later (1724) Peter the Great inaugurated the Petrograd Imperial Academy. Then came the Copenhagen Royal Academy founded by Christian VI (1744); the Hungarian Royal Academy, which now has such fine buildings, museums, etc., founded by Count Szechenyi,; and the Vienna Royal Academy, founded by Ferdinand I. All these rulers, from Alexander the Great to Ferdinand, were men of unusual sagacity and character and nothing which they did was more wise or more instrumental in perpetuating their fame than the foundation of these academies which were centers of the intellectual life of their times. The academies mentioned are provided with ample quarters, with libraries, with museums and with laboratories.

The buildings which they occupy make an imposing array—sometimes being old palaces rich with historical settings, sometimes exquisite new buildings fitted especially for the needs of the institutions.

Their libraries are often remarkable repositories of scientific literature; their museums contain extensive and valuable collections; and their laboratories are in many instances well fitted for scientific investigations.

The list of their members includes men who have made contributions to knowledge which are immeasurable in value.

In the French Academy were such men as La Place, Buffon, Lagrange, D'Alembert, Lavoisier, Fresnel, Ampere, Biot, Gay Lussac, Cuvier, Pasteur; in the Royal Society, Newton, Sir Humphrey Davy, Michael Faraday, Huggins, Lord Lister. These men met in their academies, announced their discoveries, performed their experiments, received criticism, listened to discussions, gave and received inspiration and stimulus. As a result men are today wiser, better and richer.

In return for the $20,000, which the Royal Society receives annually to aid its investigations, it has done much valuable work for the state. It has been called upon in hundreds of instances to furnish expert knowledge and advice. It has been consulted by the English government in a multitude of cases of which the following are instances: The equipment of the Royal Observatory; the question of calendar reform (the very question which our own State academy is considering at present); measurements of various kinds—the length of a degree of latitude, of the seconds pendulum, of standards of length; all kinds of surveys; expeditions to various parts of the world; questions having to do with health and sickness, malaria, trop-

ical diseases, sleeping sickness, etc. Today it stands as the venerated head of the splendid body of British Science.

Coming nearer home, our National Academy, of which many of our Illinois men are members, was incorporated with the provision that it should, "Whenever called upon by any department of the United States government, investigate, examine, experiment and report upon any subject of science or art." In return it receives support from the Federal Government.

Indiana on our east, Michigan and Wisconsin on the north, Iowa, Kansas and Nebraska on the west, all assist their academies financially. We trust that the time is now present when the State of Illinois will do likewise for this association of men who are working in every part of the scientific field for the benefit of our citizens.

In return for State aid what could the Academy offer? Consisting as it does of experts in all departments of science it could most appropriately and safely be made a legislative reference bureau of the highest type for certain things, and in a short time could more than justify its existence by expert advice. We believe that much faulty legislation is enacted. Far too often we are locking the stable after the horse is stolen. Faulty legislation may occur here, as it did in Pennsylvania in 1885, when the legislature authorized counties to pay bounties for the scalps of hawks and owls. Within a short time $90,000 was paid out in bounties. It is estimated that for every dollar saved $1,205 was paid out. The balance of nature was destroyed and within two years after the passage of the bill the farmers found their crops and orchards so completely overrun by destructive mice, rats and insects that it was estimated that $2,000,000 loss was suffered in valuable crops. California had a similar experience.

We may become accustomed, and hence able, to endure unwise legislation, but this should be avoided when among our citizens, there are those wise enough to furnish proper counsel.

Even more important than advice in matters of legislation is the promotion and diffusion of scientific knowledge among the people. Industrial research, agricultural research, medical research, all contain possibilities undreamed of by people who are not so situated as to be conversant with what these lines of investigation have to offer.

The work of chemists, physicists, geologists, biologists and bacteriologists has revolutionized our mode of life, the comforts of our homes, the health and the happiness of our people.

In fact it may be said that every great advance of mankind has been due to scientific researches and their practical application, and I believe that the State can do nothing better to advance the welfare of its people than to encourage such organizations as this Academy of Science, which aims to inspire and assist all men who are working in scientific fields.

May the time soon come when our Academy is found in an appropriate building; is equipped with a library rich in the literatures of science, as applied to Illinois conditions, and with a museum which will fittingly represent man and nature in this State.

ABSTRACT—"VOLCANIC EMANATIONS"

ARTHUR L. DAY, Carnegie Institute, Washington.

This address was chiefly concerned with the identification of and the reactions between the gaseous ingredients set free by the liquid lava at Kilauea during the summer of 1912. A successful attempt was made to collect the gases directly from the liquid lava at a temperature of about 1000° before they reached the atmosphere. The collection of volcanic gases before they have become altered by combustion with air has proved to be an insurmountable difficulty hitherto, whether the gases were collected in tubes for analysis in the laboratory or studied at the point of emergency with the spectroscope. In either case, the gases were burned or were in process of combustion, and therefore could not reveal either their true identity or the original relationships below the surface. This was the first time that unaltered volcanic gases had ever been obtained for study.

In so far as the present reconnaissance yields final results, it shows that the gases evolved from the hot lava at the Halemaumau crater are N_2, H_2O, CO_2, CO, SO_2, free H, and free S; with Cl, F, and perhaps NH_2 in comparatively insignificant quantity. No argon was found, nor any of the other rare gases.

The chief conclusion, upon finding this group of gases in association at 1000° or higher, is that they cannot be in equilibrium at that temperature and must be in process of active reaction among themselves; there can be no equilibrium, for example, between free sulphur and CO_2, nor between hydrogen and SO_2 or CO_2.

This is a conclusion of rather far-reaching consequence, for it must mean that the relative proportions of the gases are constantly in process of local change—a fact which is supported by the very considerable differences between the analyses of the gases contained in different tubes which were filled at the same time. Since these reactions are strongly exothermic, it also follows that a very large and constantly increasing amount of heat is set free during the rise of the gases to the surface. In support of this view it was also observed that when the quantity of gas set free was large, the temperature of the liquid lava in the basin was higher (July 6, 1912, 1185°); when the amount of discharged gas was small it was lower (June 13, 1912, 1070°), the quantity of lava in the basin remaining substantially the same.

Controverting a view recently put forth, H_2O was found to be present as such among the gases set free as, indeed it inevitably must be, for it has long been known that free hydrogen in association with SO_2 and CO_2 will react to form water at these temperatures.

Neither hydrocarbons nor chlorine in appreciable quantities were found.

RECENT DEVELOPMENTS IN SURGERY

Don W. Deal, Springfield, Ill.

One cannot enter upon the discussion of the recent developments of surgery without coming at once upon the part which animal experimentation has played in the reduction of human mortality.

There has been a great deal said and written on this subject—much which is sane and sound and much which is hysterical and sentimental. Medical men and scientific workers are not in any sense unmindful of the sufferings of lower animals and, in animal experimentation, pain is reduced to the minimum or eliminated altogether. In fact, it has seemed to me that scientific investigators hold these animals in higher regard—that they are appreciative of what these animals contribute to science—that they are kinder and gentler in handling them than would be many of the heart-throbbing sentimentalists.

These sentimentalists do not speak of "animal experimentation." They prefer to talk of "vivisection" which has a distressingly quivery sound like the tremulo of the fiddle in the

murder scene of a melodrama. They like to picture the eminent scientist as a hairy armed and bewhiskered individual in a blood-stained white gown, gouging at a bound-down pup with a hot poker for no higher reason than that of gratifying his curiosity as to how burning human flesh may smell.

Without detracting in the least from the glories of modern war, it seems to me that, if a dog were consulted he would gladly risk his life for the purpose of saving the lives of countless human beings. I believe this because his more intelligent human brother gladly surrenders his life, in aeroplane and submarine, for no more laudable purpose than that of depriving of life his fellows against whom he has no personal grievance.

Without experimental work with animals no scientific advance would have been possible, unless human subjects were substituted for guinea pigs in experimental work. Bed-side observations alone would not have accomplished appreciable results. They would have left us at the period of crude guess in medicine where "what's good for measles?" was the type of scientific problem which puzzled doctor's heads.

I am going to take this opportunity to criticise the people who derive a lot of self-satisfied altruism by exaggerating the discomforts of animals that are being studied.

A pamphlet recently distributed by anti-vivisectionists, calls the Rockefeller Institute, "Hell at Close Range." The anti-vivisectionists disregard all pain save that which meets with their opprobium and enables them to indulge in their favorite epithets. They strongly condemn the one justifiable pain in the world—the pain associated with the noblest of all objects—the prevention of future pain and saving of human lives.

If a man has a right to kill animals for any purpose, he has the right to perform vivisection, particularly since it is done without pain. Who is more cruel? Doctor Flexner, in devising life saving methods or the women who would shackle him, shut up the Rockefeller institute and thrust all future developments into oblivion?

These same people insist upon spaying animals by the thousands in order that beef and mutton may be tender or have a more pleasant flavor.

Think of the ospreys and egrets in the hats of these same women.

Think of a ship infected with plague and also infested with rats—the carriers of plague—about to enter port.

Do you prefer to kill the rats and so prevent them and the disease from entering the port, causing the dissemination of plague, or save the rats because the slaughter of them would be a painful procedure.

The captain who says spare the rats, is guilty of the criminal act of causing the death of many innocent human beings. So it is with the anti-vivisectionists. They see only the pain inflicted and do not heed the pain prevented. On this score they are in a sense logical when they call Lord Lister, discoverer of antiseptics, a brute, although he, of all men, has been the means of preventing the greatest amount of surgical suffering. They see only the pain which he deliberately inflicted on a few rats and rabbits, they cannot see or they refuse to see the measureless amount of misery he has prevented.

The slight pain animal experimentation causes in the world is trivial when we consider that in the universe thousands and thousands of pains, of fierce incessant struggles between living animals, are going on constantly. Every rock and every tree shelters ferocious combats and is the constant scene of painful death agonies.

Consider that in the entire world only 200,000 animals are sacrificed annually for experimentation; and that two thousand million mammals die every year from natural causes.

By giving an experimental disease to a rabbit, one scarcely changes its lot. Surely the lot of a street dog is improved when it enters an experimental laboratory.

Many anti-vivisectionists amuse themselves by hunting and fishing, while a physiologist is tremendously concerned every time he causes blood to flow or inoculates an animal with disease. I know the thoughts that animate him. The experimenter feels the responsibility of these animal lives.

These men pass their lives in nauseous rooms, amidst poison and virus, receiving no other compensation for long labors than the satisfaction of duty accomplished. It is not in the laboratories of the physiologist that a man grows rich.

Let us consider whether the efforts of experimenters and the sacrifice of animals has paid.

In 1906, Dr. Flexner at Rockefeller Institute, developed a serum for meningitis and sacrificed 25 monkeys and 100

guinea pigs. This one experiment saves thousands of human lives a year.

Careful scientific experimentation has developed a serum for meningitis which directly destroys the growth of germs. As a result the mortality of the disease has been reduced and severe symptoms and crippling complications have been prevented.

In 1878, Koch discovered the tubercle bacilli. Before that time it was thought that tuberculosis was due to a divine anger. Since then tubercular mortality has been reduced 50 per cent. Since Koch, six million people have been saved by progress in hygiene. It has been clearly shown by experimentation that tuberculosis is not inherited.

Animal experimentation has made a rich contribution to children. I fear laymen are insufficiently informed on these important subjects. Hysterical imaginines would discredit this beneficial work. The ones to suffer most from a suppression of animal experimentation are helpless suffering children.

As an illustration, let us consider the ravages of diphtheria in New York City, prior to the use of antitoxin. In 1894 there was a mortality of more than eleven thousand children, while ten years later, after antitoxin had been well introduced, the mortality was but slightly over two thousand. A saving of mortality in one city in one year from one disease was practically nine thousand. It is estimated that since Behring discovered diphtheria antitoxin, one million, three hundred and fifty thousand children in France alone, have been saved by its use. Behring sacrificed one hundred rabbits and twenty-five dogs to make this discovery. In 1895 the mortality rate from diphtheria in nineteen American cities was eighty per one hundred thousand. Ten years later it was seventeen per one hundred thousand. If this rate could be applied throughout the United States, it would mean today an annual saving of sixty thousand children as the result of antitoxin treatment and public health laws.

I wish that the people trying to throttle scientific research, would witness the awful struggle of a child dying from diphtheria croup. Surely they could then realize the importance of these discoveries. Fortunately few physicians are forced to go through such an ordeal at present owing to the beneficent results of treatment resulting directly from animal research.

Hydrophobia has been almost stamped out; and so has benefited dogs as well as human beings.

Smallpox has been practically eliminated in civilized countries by vaccination. During the eighteenth century, sixty million people died of this disease in Europe and multitudes were permanently scarred. The reign of this destruction and death continued until Jenner's discovery in 1796. In Germany, where compulsory vaccination has been enforced, there has not been an epidemic for many years. Adjacent countries not so protected have had numbers of epidemics.

Typhoid fever in armies has killed and maimed more than bullets. In the Spanish-American War, one-fifth of the soldiers in national encampments had typhoid fever. Among one hundred thousand men there were twenty thousand cases and sixteen hundred deaths.

In 90 per cent of volunteer regiments the disease broke out within eight weeks after going to camp.

Contrast this to the recent mobilization in Texas, where but two cases of typhoid developed and both recovered. In 1898 at the Jacksonville camp, with practically the same number of troops, there were two thousand cases and two hundred and forty-eight deaths.

In operative surgery wonderful strides have been made.

Anti-vivisectionists would be content to use the same old horribly dirty methods of surgeons employed in the days before Lister, and thereby offer up thousands of human lives to their Moloch. Lister's discovery of antiseptics has reduced the mortality in simple amputation from 70 per cent to practically nothing. Lord Lister in 1868 sacrificed a few guinea pigs and rats, and we have the above results.

The most useful advances in surgery are not necessarily those which are the most spectacular, nor are these advances based upon accidental or sudden discovery. A great many people have the idea that animal experimentation or other scientific research, consists in striking about hit or miss in the hope that some valuable fact may accidentally show itself. Nothing could be further from the truth. The scientific student starts out with a carefully elaborated theory or belief, to which he has given the utmost thought and his experimental work is conducted along a well prepared plan for the purpose of proving or disproving his preconceived theory.

One of the most interesting developments in surgery of the present generation is that which has as its purpose, the re-

duction or elimination of so-called "shock," with the purpose of returning the patient to his active vocation in the shortest possible time and of causing the individual the smallest amount of injury through the operation itself.

With all of the benefits which come from properly conducted surgical operations, intelligent surgeons have always recognized that the ordinary administration of ether or chloroform and the ordinary surgical procedure, are accompanied by a certain amount of psychic and physical violence which make their impress upon the mind and body of the patient with certain definite prejudicial results.

This injury is caused in several ways. First, there is the element of fear. Second, the powerful impression carried to the brain through the violence done to the tissues involved in the operation. Third, the depression caused by the deep intoxication of prolonged anæsthesia.

To overcome this element of shock there has been devised a method known as the Nitrous Oxide Oxygen Anosi Association. The process is relatively new, but I am satisfied, from a personal experience of several months, that it is a method which will eventually be adopted by the conservative surgeons of the world.

Briefly, this Anosi theory, as taught by Crile, of Cleveland, assumes that potential energy is stored in the brain, the liver and in suprarenals, and that when this energy is destroyed in sufficient amount, there results a condition known as exhaustion or shock. This discharge of potential energy may be brought about by any insult to the body such as trauma, hemorrhage, starvation, worry, excitement or insomnia, and is produced to an enormous extent in ordinary surgical operations and this discharge is occasioned in surgical operation, although the patient may be thoroughly anaesthetized and unconscious of actual pain. The unconsciousness does not prevent the transference of sensation from the field of operation to the brain, although the patient may be oblivious to the pain which would thereby be occasioned were he awake.

The Anosi Method of handling the patient for surgical operation consists of the following logical steps:

1. The element of fear is eliminated as far as possible, the attitude of the surgeon and his assistants is essentially optimistic and encouraging. The patient is given a preliminary injection of morphine and scopolamine to quiet his anticipation and to reduce the amount of anæsthetic required.

2. On account of its peculiar action upon the brain cells, ether is in itself a shock producing factor, and so in this process we have adopted nitrous oxide, which prevents oxygen reaching the brain. Crile has demonstrated that an operation under ether produces three times the amount of shock that the same operation does when performed under nitrous oxide, and he also shows that the blood pressure under ether falls two and one-half times greater than under nitrous oxide anæthesia.

3. The psychic effect of taking ether is much greater on account of the rather disagreeable odor, and the sense of choking and suffocating occasioned by it, while nitrous oxide is entirely odorless and only a few inhalations will produce unconsciousness.

4. Ether is known to destroy the white cells of the blood, which, as you know, are the natural protectors of the body from bacterial infection. Hence, to a certain extent, ether promotes infection by breaking down the natural resistance to infection.

5. Many surgical operations are known as two step operations, in that they have to be performed at two sittings. Ether anæsthesia is so disagreeable that the patient usually approaches the second operation with the utmost apprehension, while the Anosi Method is so far from being disagreeable that the patient has no fear of the second anæsthesia.

6. To overcome the depressing effect of ether, major operations under local anæsthesia or under spinal anæsthesia were suggested, but it was found that even if these operations were entirely free from pain, the consciousness of the patient that violence was being done to the body, was sufficient to produce considerable shock.

7. Having produced unconsciousness by the method most agreeable to the patient, the Anosi Method includes blocking off the field of operation with a local anæsthetic so that the impulses of the operation are prevented from reaching the brain. In this combination we avoid the psychic stimulation of the brain cells by unconsciousness, and also protect the brain from the shock due to disturbance in the operative field. The method also involves the handling of the operative field with the utmost care on the part of the surgeon.

With an operation conducted with prevention of shock or violence, post-operative nervous exhaustion is almost eliminated and, by blocking off the incision with a solution of

quinine and urea hydrochloride, post-operative pain becomes a negligible factor.

Under this method I have had the gratifying experience of having a patient operated upon for appendicitis, removed from the operating table to a wheel chair and permitted to dress and walk about the hospital within six hours after the operation.

When through ether it was found possible to make surgical operations painless and when through asepsis it was found that infection could be avoided, we had a comfortable feeling that we had solved the great problems of surgical procedure and that there were few, if any, great cardinal principles yet to be discovered.

This recent discovery of the element of shock in surgical operations leads us to believe that there is still much to be discovered and that perhaps there yet remains unknown some great factor in surgical development quite as important as anæsthesia or asepsis. Certainly the prevention of shock may be placed on a par with these two great epoch making discoveries.

Symposium on Colloids

OUTLINE OF THE PHYSICAL CHEMISTRY OF COLLOIDS

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In the short time at our disposal it will be possible only to discuss some of the outstanding features of the physical chemistry of colloids. Since the first use of the term "colloid" by Thomas Graham in 1861 the subject has advanced so rapidly that no one but a specialist could hope to read all the literature connected with it. There are at present two journals devoted to colloids; the "Kolloide Zeitscrift" and the "Kolloide Beiheft," both edited by Wolfgang Ostwald. Extended treatises on the subject have been written by Ostwald, Zsigmondy, Hatscheck and others, and scientific journals of the most diverse character will be found to contain articles pertaining to colloids at least a few times a year.

In order to get a rough idea of the place colloids occupy in nature let us make the experiment of shaking up some soil in water. There will be a certain portion that will settle out almost as soon as the shaking ceases. Another portion will remain suspended in the water for a short time, but will be separated if the mixture is run through a filter paper. This is usually termed a "coarse suspension." The turbid fluid that has gone through the filter is a colloidal solution. The solid it contains differs from the portion that remained on the filter paper chiefly in the fineness of division of its particles, or in terms more usual in this branch of science, the degree of dispersion of the particles. We may then, following Wo. Ostwald, take the size of the largest particle that will go through a filter paper as the upper limit of the size of colloidal particles. The arbitrary nature of this division will be evident to everyone, but it is in accord with the general usage of chemists. If a precipitate is not stopped by a filter paper a chemist makes expressive remarks concerning colloids. The lower limit of the degree of dispersion of colloids we may also take from Ostwald. This may be given as the size of the smallest particle that will be briefly described later. Now the diameter of the particles that an ordinary filter paper will pass is about 100 $\mu\mu$, or 1-1000 millimeter, and the ultramicroscope can make evident to the eye particles of a diameter of $6\mu\mu$, or six millionths of a millimeter in diameter. We can then agree for the present to consider solutions containing particles of sizes that come within this range as colloidal solutions.

The first investigators in the subject thought that but few substances can be obtained in the colloidal condition. Later, and as the result of an enormous number of researches, it has become evident that practically any solid or liquid substance may, by proper manoeuvering, be obtained in colloidal solution in some solvent. The method of preparing colloidal solutions are quite diverse as a consideration of the following typical examples will show.

(a) A colloidal solution of silver chloride may be prepared by mixing a very dilute solution of silver nitrate with a very dilute solution of common salt. The use of very dilute solutions is a method of producing colloidal solutions of many slightly soluble substances.

(b) An interesting series of colloidal solutions of gold may be prepared by treating gold chloride solutions with reducing agents. These vary from the translucent blue to the transparent orange red solutions. In the latter the gold is in such a fine state of division that the separate particles are scarcely visible in the ultramicroscope.

(c) A colloidal solution of ferric hydroxide may be prepared by simply pouring a few drops of ferric chloride into boiling water.

(d) Bredig's method, which is applicable to a number of metals, consists in causing an electric arc to strike, under water, between electrodes made of the metal of which a colloidal solution is desired. With the use of high frequency alternating currents this method has recently been used in the preparation of colloidal solutions of a number of metals in a great range of degrees of dispersion.

(e) Colloidal tungsten and chromium may be made by treating the finely ground metals alternately with acid and alkali. This is known as the etching method. Colloidal tungsten prepared in this way was used in the manufacture of the early fragile tungsten filaments.

(f) It has also been found possible to prepare colloidal solutions of a number of metals simply by keeping them for a long time in boiling water in the absence of oxygen.

The question now arises; what properties in common have solutions prepared by such different methods and involving such different substances? The size of the particles has already been mentioned, some other properties will be considered in the following paragraphs.

One very interesting and important property of colloidal solutions can be observed only with the ultramicroscope, an instrument which renders the separate particles visible. Under this instrument the particles are observed to be in motion, the more rapid the smaller they are. This phenomenon is known after its discoverer as the Brownian movement. A study of this motion has led in the last few years to a virtual proof of the molecular theory of matter. A review of the work in this field as carried out by Perran and others will not, of course, be possible here. Briefly, however, the basis of it is as follows: In order to account for the observed properties of gases the kinetic theory has postulated that at a given temperature the kinetic energy of all gas molecules is the same. Since the kinetic energy is the product of the mass of the molecule and the square of its velocity, the speed with which a large molecule moves must be smaller than that of a small molecule. On the assumption that the colloidal particle is a very large molecule, it is found that the directly observed velocity of the particles has exactly the value predicted by the kinetic theory of gases.

The optical principle of the ultramicroscope, which has made this and many other investigations on colloids possible, is shown in figure 1. The cell *E*, which holds the colloidal

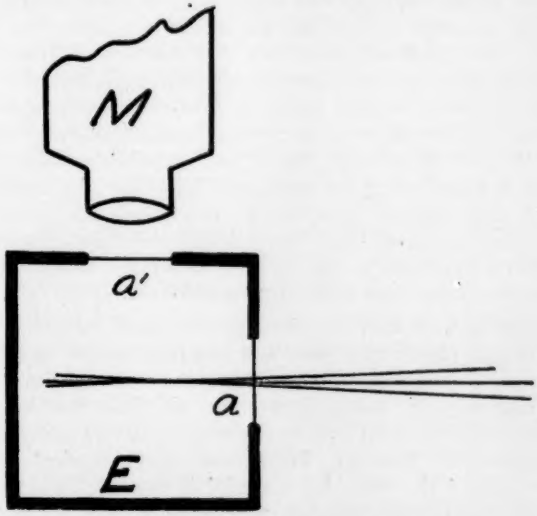

Figure 1. Principle of the Ultra Microscope

solution, has two thin quartz windows, *a* and *a'*. By means of a slit and a series of lenses, rays of light from an arc light enter window *a* in a plane a few thousandths of a millimeter thick. This light impinges on a few of the colloidal particles in the solution and causes them to be centers of light emission. The effect can then be observed by means of an ordinary microscope, *M* against a black background through window *a'*. The same principle is, of course, involved when a ray of sunlight enters a darkened room and makes brilliant spots of light of the motes in the beam.

A property common to colloidal solutions is the slow diffusion of the particles through gelatinous substances and through membranes. Upon this property is based the easiest method of determining whether a solution is colloidal or not. A test of this kind can be made by pouring some gelatin in the bottom of test tubes, and on top of the gelatin solutions of, say, colloidal gold and of potassium dichromate. After an hour or so it will be observed that the dichromate has diffused several millimeters down into the gelatin, whereas the boundary between the gelatin and the colloidal solution is just as sharp as at the beginning of the experiment.

The surface exposed by the colloidal particles to the solvent is, as a simple calculation will show, enormous, so that surface effects that are very slight with ordinary solids may be greatly increased by getting the solids into the colloidal condition. One such surface effect is *adsorbtion*. Willard Gibbs's reasoning led him to the conclusion that any substance the addition of which lowers the surface tension at a solid-liquid or gas-liquid surface is in greater concentration at that surface than in the bulk of the liquid, in other words, the substance is *adsorbed* at the surface. This has been amply verified by experiment. Adsorption phenomena play a large role in the theory of colloids. It can readily be shown that adsorption has a large part in the catalytic effect of colloidal platinum on the decomposition of hydrogen peroxide.

Under most conditions the colloidal particles are found to be charged electrically and will migrate to one pole or the other when an electric current is passed through the solution. The origin of this charge is not entirely clear, and its magnitude and even its sign may be changed by the addition of small quantities of electrolytes. If by some means the electric charge is neutralized the colloidal material is rendered unstable and may be readily coagulated or precipitated.

Of the three general types of colloids only one, the *sol*, has been mentioned in the preceding discussion. A *sol* may be defined as a solid dispersed in a liquid medium. Discussion of the *emulsoids*, or liquids dispersed in liquid media, and of *gels*, or liquids dispersed in solid or semi-solid media, must be omitted both because of their complexity and because of lack of time.

In conclusion, it may be said that the scientific and practical results of the study of colloids have amply repaid for the arduous researches made upon them and we may look for similar if not greater results from the researches to be made in the near future.

SIGNIFICANCE OF COLLOIDAL CHEMISTRY IN PHYSIOLOGY

By William Crocker, University of Chicago.

I. INTRODUCTION

Were we to put today to a large number of physiologists the question, "How much, in your opinion, will the laws of colloidal chemistry illuminate and explain physiological phenomena?" we would get a great diversity of opinion. We would find on one extreme those who believe that the newer branch of chemistry has not led and will not lead to any considerable advance in physiology and, on the other, those who see almost all the problems of biology rooted in colloids and almost all the phenomena peculiar to the living organism finding explanation in the simple laws of heterogeneous systems. With colloidal chemistry in many of its phases a new science and with many of its fundamental laws even now just being established, it is evident that the application of its principles to the complex phenomena of living organisms is a thing to be done with some caution.

The application of the laws of homogeneous solutions to biology has already answered many questions and is still to answer many more. It is likewise evident that it will leave perhaps a greater number, unanswered or explained only on the assumption of vital principles. The laws of heterogeneous solutions are now having their turn at vital problems with excellent prospects of solving many of these along physical chemical lines. To date, however, the significance of colloidal chemistry in biology is more a matter of hope and excellent outlook than of actual accomplishment. This prospect can

best be put by a quotation from Höber (1)*: "Biology experiences extraordinarily valuable stimuli as soon as many of its old problems are considered from the standpoint of colloidal chemistry. Consequently every attempt, in any degree possible, to interpret those problems, hitherto not completely understood, into colloidal processes is not only desirable but to be demanded. The materials of the biologist offer sufficient reason for this. For the microscopist must daily consider colloids, when he deals with the effects of fixing, macerating, and staining reagents upon the structures of protoplasm, for visible evidence of these effects rests mainly upon the visibility of solid or precipitated colloids; the medical chemist deals particularly with colloidal albumin bodies: whoever undertakes problems of metabolism finds that most of his riddles are bound up, in a large measure, with colloidal ferments and any one who undertakes in these days the analysis of any fundamental physiological phenomenon will observe that it is not in vain that protoplasm consists largely of colloids, that all of the more delicate and grosser membranes, which serve for the isolation and regulation of biochemical processes, are colloidal membranes. It may be emphasized that a study of immunity reactions presupposes a knowledge of colloidal properties, since toxins, antitoxins, alexins, agglutinins and lysins are colloids."

II COLLOIDAL NATURE OF LIVING CELLS

The structure of the protoplasm, its organs and the parts produced by it, has been the phase of biology of perhaps most general interest to which the knowledge of colloids have contributed. The students of colloids are coming more and more to view the protoplasm and its individual organs as typical hydrosols or as hydrogels, and it must be acknowledged that they are accumulating much evidence for this conception. From this viewpoint the following are the more prominent of the questions worked upon. In how far are the structures of the cell and its accessory parts hydrosols and how far hydrogels? What are the structure of gels and sols in general, including the protoplasmic gels and sols? Are colloidal structures complex enough to satisfy the demands of protoplasmic processes.

In answering the first question Czapeck (2) states that cell membranes, gums and starch grains are gels, as well as a number of protoplasmic organs, such as nuclei and many chromatophores.

*Figures in parenthesis refer to the bibliography at the end of this paper.

Kite (3), in work marked by excellency and delicacy of technique, has done much toward answering this question. By using an adaption of the Barber pipette as a dissecting knife he has cut away various portions of a considerable number of different sorts of plant and animal cells, determining the consistency, elasticity, and other physical characters of various cell organs. His work shows that protoplasmic parts are much more frequently gels than is generally supposed, and that the same organs in cells of different organisms may have very different characters. The nucleus of Asterias egg is a free flowing sol covered with a very tough consistent membrane and bearing a nucleolus of rigid cohesive granular gel. The nucleus of Spirogyra is a gel of rather slight viscosity bearing a network of granules and strands of greater consistency. The nucleus of epithelial cells of Necturus is a gel of greater viscosity bearing areas of rigid granules, giving an appearance of threads. Chloroplasts and many other organs show great range of viscosity, varying from sols to consistent gels. Kite finds that in general the animal cells are more viscous and consistent than the corresponding organs of plant cells.

There is no reason for believing that there is a transformation from gels to sols and vice versa, with a change of conditions in protoplasm as in vitro. The conditions important in producing such transformations are temperature changes, changes in hydrogen, hydroxyl, and salts ion content.

As to the second question—structure of gels—there are two rather distinct pictures. One was developed by Bütschli and confirmed and extended by Van Bemmelen (2, p. 10). They consider gels to be solid colloids with solid dispersal medium and fluid disperse phase. This is Bütschli's well-known foam structure. The frame work of the gel consists of the gel forming materials with little water imbibed, surrounding numerous spherical cavities filled with a water rich hydrosol of the gel forming material. This foam structure can be seen with the microscope in many hydrogels, especially after displacing the water with alcohol or after slight drying. The mesh size of the foam structure varies considerably with the sort of gel studied and in some is apparently ultramicroscopical. The people holding this view of gel structure extend it to hydrosols as well, so even the more fluid portions of the protoplasm are conceived as foam-like.

This picture of hydrosols is very different from the more strictly colloidal conception (1: pp. 312-316). According to the latter view hydrosols consist of discrete particles of the colloid dispersed in water. In the hydrophyllous group the

particles are more or less swollen by the absorption of water. The advocates of this view extend this conception of hydrosols to hydrogels. In the gel the imbibed or hydrated particles crowd upon each other, giving high viscosity.

It is estimated that in a 6 per cent casein solution the swollen submicrons or amicrons occupy about 60 per cent and in a 9.4 per cent solution about 80 per cent of the space of the total solution. There are several reasons offered for postulating this structure. Both a gelatin solution too dilute to gel and one sufficiently concentrated to gel show numerous submicrons as they cool, but no difference between the two can be detected by the ultramicroscope. Each can be flocculated by salt additions with the same relative effectiveness of the ions. There are points of similarity between the phenomena resulting from mixing with water certain hydrating crystalloids like sulfuric acid and glycerin and those of swelling gels. High dispersion of these gels along with their hydration gives them many of the characters of true solutions. The degree of dispersion of gelatin is not known, but it is certain that haemoglobin forms a molecular solution.

It is not believed that the foam structure of Bütschli and VanBemmelen is an ever present structure of gels. It is considered that the foam structure is one of several deformations produced in gels by a variety of reagents or by pressure and temperature changes. A number of workers have studied separations of this type produced in gels and sols. We may draw a good illustration from Hardy's work (4). He found that when gelatin was treated with concentrated sublimate or other killing or fixing agents a variety of structures appeared depending upon the concentration of gelatin and the reagent used. From dilute solutions treated with sublimate the gelatin falls out as individual granules, from medium concentrations as a network of granules and in concentrations of 5-7 per cent or above a foam structure appears. The more concentrated the gel the thicker the walls of the foam and the smaller the enclosed cavities. In 10 per cent gelatin the cavities were 7μ in diameter and in 50 per cent gelatin 2.5 μ in diameter. These reactions were reversible or irreversible, depending on the reagent used. Protoplasm shows very similar behavior in all respects with perhaps a greater sensitive to reagents, both as to deformation and irreversibility, and these reactions may in large part explain the various theories of protoplasmic structures. It seems established now that these reversible flocculations occur in normal living protoplasm. The irreversible ones, if extensive, lead to death.

In protoplasm the multiple vacuolate condition may have another origin as is shown by Bensley (5), in his late work on the canalicular systems of plant and animal cells. He concludes with the sentence, "I regard, therefore, the canalicular system as the true condition intra vitum of the vacuolar apparatus in these cells of the root tip, and believe that the multiple vacuole condition is of secondary origin due in most cases to injury of the cell." Here while the origin of the multiple vacuolate condition is different from that found by Hardy in gelatin gells, it is nevertheless a deformation of the prevailing structures.

In answer to the third question above, Are colloidal structures complex enough to satisfy the demands of protoplasmic processes? it should be stated that many reactions are occurring in a cell coincidently—reactions of the most diverse character and of antagonistic types. On this basis Hofmeister (6) believed there must be a special structure offering compartments separated by membranes of special permeability characters to isolate and regulate these reactions. This he thought doubly necessary for cells with few special organs. The foam structure of protoplasm cares amply for this chemical necessity, especially if the walls of the foam are endowed with permeable qualities varying with conditions and with location in the cell.

Some of the students holding to the more strictly colloidal conception offer a number of arguments against this view. Protoplasmic movements argue against such a structure. The ultramicroscope generally fails to reveal foam structure in gels and sols in vitro as well as in the protoplasm. Such structures are apparently not ever present, but are formed as a result of certain accompanying conditions.

As our intra vitum staining methods improve and as new methods of the direct study of the living protoplasm are developed, such as the dissecting method of Kite, we are finding more and more bodies of micronic size in the cell. These are included under a variety of names such as mitachondria, chondriasomes, etc. If we remember that colloidal particles of this nature generally surround themselves with special membranes, which give them peculiar permeability characters, it is easy to see that here again is the possibility of the isolation and regulation of chemical reactions. Aside from these the ordinary plant cell has plastids, vacuoles, or canalicular systems and nuclei.

If in the frame-work and cell wall systems of plants in general such a simple structure is primary, there must also exist a secondary and grosser structure which determines the anisotrophy as manifested in unequal swelling along the several axes due to water absorption. Wood, for instance, swells most tangentially, less radially and least longitudinally, while a great variety of unequal swelling appears in wall structures showing hygroscopic movements. In some of these cases only a single wall is involved, showing anisotrophy to exist in rather minute structures whether primary or secondary. The multivacuolate conception of gel structure lends itself more readily to the explanation of this anisotrophy, for with water gain and loss the vacuoles may show greater dilation and contraction in certain axes than in others (7: pp. 745-552).

The thing of greatest biological interest in the study of hydrosols and hydrogels, including the protoplasm, is not any specific structure found, but the capacity for the assumption of one or another structure with variation in condition. The reaction is now reversible and now irreversible. While such modifications are brought about with relative ease in gels and sols in vitro, it seems that living protoplasm and its constituents are even more labile. This is illustrated by Lepeschkin's (8a) work showing that slight pressure will cause a reversible flocculation of cell proteins of Spirogyra and greater pressure, a permanent coagulation and death. Pressure alone does not coagulate protein in vitro. According to Lepeschkin some of the proteins of plant cells essentials to life would coagulate in a few hours, or at most a few days, at 20° C, if there were not dispersion processes in the living cell counteracting the coagulation processes (8b). The proteins in vitro at the same temperature require thousands of years for coagulations.

The way investigators of colloids are attempting to change our conception of the structure of living matter is well illustrated by the work on the ordinary green chloroplast. Earlier work indicates a definite structure of this organ, but different investigators give very different pictures. One speaks of the cytoplasmic stroma as a sponge-like framework with definitely organized granules of pigment filling the cavities, another of the pigment itself in the framework with the protein filling the cavities, and a third of the surface distribution of the pigment. Liebaldt (9) has lately studied the structure of this organ from the standpoint of colloids and finds that the normal living chloroplast is generally homogeneous when viewed either with the microscope or the ultramicroscope. Allowing

for oil droplets and starch grains she speaks of the lipoid pigment phase as distributed through the hydroid protein phase to amicronic dimensions. This distribution is easily deformed by various reagents giving all types of structure formerly claimed for the organ. Excessive water absorption caused by opening the cells and bringing the chloroplasts directly into contact with water or even by long soaking of the entire leaf, produces a variety of deformations. As shown by staining reactions, water never produces a complete separation of the two phases. Such altered structures appear frequently in nature and they probably result from peculiar water relations of the plastid. Surface tension active substances as well as other fixing and killing agents in sufficient concentration cause a complete separation of the two phases. This emphasizes the great danger of concluding as to the structure of a living cell from fixed and stained material. (See also citation 4).

Other evidence is offered for the colloidal state of chlorophyll in the living plastid. It has been known for a long time that chlorophyll in an alcohol solution is readily decomposed by sunlight. This has called for an explanation of the apparent or real light stability of chlorophyll in the illuminated leaf. Wiesner believed that protective action of fatty bodies and continual synthesis account for the maintained amount, while Reinke suggested that chlorophyll forms a light stable compound with proteins of the plastid. Iwanowski (10) accepts neither of these views, but thinks the light stability of chlorophyll is explained on the basis of the colloidal condition in the plastid. He found chlorophyll extract in 49 per cent alcohol far more light resistant than that in 95 per cent alcohol. In the former case it is in colloidal solution, in the latter molecular. He also shows that as the colloidal concentration of the solution increases and the degree of dispersion correspondingly decreasess light stability rises. Finally in the concentration and degree of dispersion probably existing in the chloroplast, it is light stable. While the Iwanowski conception has evidence in its favor there is also no important evidence against the Reinke view. Iwanowski also finds evidence for carotin and xanthophyll of the plastid protecting the chlorophyll against light destruction. Herlitzka (11), using carefully purified chlorophyll, finds that it shows little if any fluorescence in collodial solution, while this property is very evident in a molecular solution. The lack of marked fluorescence in the plastid is probably due to the colloidal state of the pigment as well as to the turbidity of the plastid, formerly offered as the explanation.

III SOME GENERAL CHARACTERISTICS OF CELL COLLOIDS

The protoplasm is optically isotropic, while some of its products (starch grains, cell walls and crystalloids) are optically anisotropic. It is believed that the double refraction of starch grains and cell walls can be explained on the basis either of impregnating materials, as in the cuticle, or tension within the gels of these structures; and that the property furnishes no argument in favor of their crystalline structure as against their hydrogel nature (1). With time, however, it seems that the line between crystalline and amorphous bodies becomes distance. (12: pp. 66-75).

The colloidal constituents of the living cell bear negative charges. As a result living cells themselves are electronegative. This has been shown for lecithin, chlesterin, proteins, chlorophyll, blood corpuscles, bacteria and spermatozoa.

When Graham divided matter into two classes—crystalloids and colloids—he thought these two divisions were quite distinct. One of the principal characteristics for distinguishing the two classes was their diffusibility through gelatin or other colloidal membranes. We know that the two classes of substances are not so distinct but that colloidal solutions range in their degree of dispersion from suspensions with microscopically visible particles, on one extremity to molecular dispersions on the other. The hydrophyllous colloids of the living body, which are of greater interest to the biologist, are very highly dispersed, approaching in general the molecular state. It is now well known, for example, that hæmoglobin forms a molecular solution. Along with this very high dispersion they have the character of diffusing with ease through a variety of colloidal membranes. Egg albumin and hæmoglobin diffuse through gelatin plates. Pepsin diffuses into cubes of coagulated albumin. The immunity bodies diffuse through a great variety of colloidal membranes (gelatin and agar plates, dead intestine walls and others). This raises the question of how they are retained within the living cell. This question becomes especially urgent if Ruhland (13) is correct in his conclusion that for colloidal solutions the protoplasm acts as an ultra filter. We shall later see his explanation for the retention of certain enzymes by the cell and their localization within it.

IV WATER RELATIONS OF CELL COLLOIDS

There are certain characters of hydrophyllous gels and sols that are assuming great importance physiologically. One of the more significant is the water absorbing power of these as affected by various reagents. Water absorption by gels and

sols is often spoken of as hydration, although this is strongly condemned by Van Bemmelen as incorrectly emphasizing chemical union of the water with the colloid. A great part of the knowledge in this field we owe to the efforts of Martin Fischer (14). The more significant facts known for gelatin and fibrin are: acids, alkalies and urea greatly increase water absorption; some anions of alkali metals increase water absorption (Rhodonate Cl, Br, NO_3.) and others decrease it (SO_4, PO_4, Tartr., Citr.) (2: p. 43); salts in general inhibit the hydrating effects of acids and bases and the total effect of the salt is due to the joint action of the two ions; non-electrolytes show influence on the hydration effects of acids and alkalies; sugar and other non-electrolytes reduce greatly the hydration effects of urea, while electrolytes show little influence. Fischer finds these reagents act on the hydrophyllous colloids of the body, especially the proteins of the cells and fluids, exactly as they do upon gelatin and fibrin. He concludes from his work that dropsy in the animal body is produced by the presence of agents that favor water absorption by colloids of the body. Amongst these, acids and urea are the more important. Intravenous injections of salts, alkalies and dextrose are effective in reducing edema by dehydrating tissues and fluids of the body on the same basis as they act on gelatin and fibrin. In fact he finds the cause and therapeutics of dropsy tied up with water absorption by body colloids. From this extensive work Fischer concludes that absorption by colloids and modification of it by various factors play the main part in water relations and secretions in the animal body; while osmotic pressure is of very minor importance. This is a reversal of the general view and brings colloids into prominence in contrast to crystalloids, which, although they act by the help of colloidal semipermeable membranes, are the main source of osmotic pressure.

Whatever may be true in the animal, one who knows the very extensive literature on the water relations of plants cannot give osmotic pressure such a minor role there. It is probably just as true that the significance of water absorption by colloids has been greatly underrated in plant physiology. This is due to the over shadowing prominence given to osmotic pressure and the resulting turgor pressure. We generally think of the plant cell with its large vacuole and cell wall as pre-eminently an osmotic machine. One is surprised when Borowikow (15) announces that a root placed in .01 M. HCl elongates twice as fast as in distilled water. It behaves much like a piece of gelatin, although it ought to exhibit osmotic

activity at its optimum. The elongation is of course temporary for the high concentration of acid soon proves fatal. Lower concentrations of acid increase the rate of elongation, but less considerably and for a longer period. There seems to be evidence for the view that rate of growth in plants is regulated to a considerable degree by organic acids formed (15, 16, 18). Whether this is due in the main to the hydration effect of the H+, or whether the acids also favor the formation and activation of enzymes, or perhaps other processes are effective, is not established.

Acids and bases increase the rate of water absorption by seeds and they are good forcing agents for many seeds (16, 17, 18). This forcing effect in some cases is due to increased water absorption by the seed coat. In other seeds the reagents have this and other effects upon the embryos. I shall be surprised if the often mentioned forcing powers of neutral salts for seeds is not due in many cases to its effect upon water absorption by gels of the seed coats and the endosperm. Assuming that these gels are electro-negative one would expect such salts as lithium, sodium and potassium chlorate, nitrate or chloride to increase water absorption while salts involving calcium or sulphate might have the opposite effect.

As yet, however, we know very little about the role of these reagents in water absorption by carbohydrate gels, which are so prominent in seed coats. There are peculiar cases (19) recorded, such as the power of potassium salts to increase the water absorption and cause the final dissolution of the cell walls in the growing zone of roots.

Calcium salts alone or in combination with other salts on the other hand, maintain the proper consistency of the walls and integrity of the roots. In fact Cranner finds that in general potassium salts greatly favor the absorption of water by cell walls and inhibit the evaporation of water from them; while calcium salts have the opposite effect. The effect of these salts upon water absorption and retention by the cell wall is similar to their effect upon transpiration which indicates that they modify the latter process, at least in part and perhaps in the main, quite independent of the protoplasm.

Calcium ions tend to maintain the proper consistency of the intracellular cements of animal cells, while potassium ions lead to their dissolution (1).

In this connection we should mention certain effects of calcium and other bivalent and even trivalent ions upon the protoplasm. They reduce the permeability of the protoplasm

(plasmahaut?) to salts of the alkali metals and many other substances (20, 21), thus probably reducing the toxicity of these substances to the organism. This effect has been described under the term antagonism. Recognizing Cranner's contribution, wall as well as the plasmahaut effects may be involved in antagonism[1]. It is also not proved that antagonism results alone from permeability change. It may include adsorption phenomena (2: p. 60; 21) or something quite different, such as induced or stimulus effects rather than direct physical changes.

We might summarize what we have said on the relation of various substances (ions and molecules, especially of salts, acids, bases and anesthetics) upon colloids of the living cell. In certain concentrations and mixtures they maintain the consistence and other physical characters of cell colloids necessary for the proper functioning of the organism. Höber and others emphasize in this connection the colloids of the plasmahaut and believe that the effect of these substances upon the irritability, permeability (35), *etc., of the organism can largely be explained through their effects upon this organ* (1:pp.—). *Cranner* (19) *would emphasize in addition their importance in maintaining the proper consistency of the cell walls in plants; while Martin Fischer sees no less significance in their effects upon all colloids of the organism, including sols as well as gels.*

Besides the general nutrient function of salts in plants, such as the use of nitrates, phosphates, sulphates and magnesium for the synthesis of proteins, nucleoproteins, lecithin, chlorophyll, etc., all salts or rather all ions of salts have effect on the physical characters of the colloids of the organism. The necessity of calcium for most plants can best be explained today by its function in maintaining the proper consistency of the colloids of the organism wall and protoplasm. We have much yet to learn concerning calcium in this regard and even more concerning potassium, magnesium and other ions[2].

There is evidence that some very important morphogenic or development changes are brought about by changes in the amount of water held by cell colloids at the time particular processes are occurring in the organism. Certain work indicates

1. Indeed it is not established that the plasmahaut alone determines the entrance of materials into the cell. Other layers of the protoplasm may be involved and in plants the permeability characters of walls and change of these with conditions should not be neglected. This is especially emphasized by recent study of many walls in seed coats showing peculiar osmotic characters in part at least resembling those of the plasmahaut.

2. This is not denying still other functions of salts in plants.

that sex may in some cases be determined by the water content of the egg colloids at the time of fertilization. Eggs of frogs fertilized when laid give about half and half male and female. If they soak in the watery fluids of the oviduct of the female for some hours or days before fertilization they give predominently (sometimes 100 per cent) males. If toad eggs are fertilized as soon as laid they produce about half males and half females, but if dessicated before fertilization females dominated, in some experiments 9 to 1. In hybrids between certain pigeons Riddle finds high water content of the yolk generally correlated with maleness and low water content with femaleness (22).

On the plant side also there are results that may be interpreted as meaning that water content of cell colloids of various primordia have a prominent part in determining the course of development of those primordia. According to MacCallum (23) the markedly different type of leaves in Proserpinaca palustris developing in water and air is due to differences in water contents and Klebs (7: p. 488) finds that in flowering plants high water and salt supply (especially nitrates) leads to vegetative growth, while low water and salt (especially nitrates) along with high carbohydrates induced reproduction. The nitrates here belonging as they do to the least hydrated end of the lyotropic anion series may act similarly to greatly increased water supply by inducing greater hydration of the cell colloids[1].

From these illustrations the question naturally arises: Why does the degree of hydration, or water imbibition, by the protoplasm play such an important role in the course of development of the primordia? The question is not capable of answer at present. It should be pointed out, however, that many other physical characters (viscosity, degree of dispersion, etc.) of the colloidal mass vary correlatively with water supply[2].

In the mammal nervous control and internal secretions, acting perhaps through correlations, are two very important morphogenic determiners. If the degree of hydration of colloids turns out to be as significant as the illustrations above indicate we have here a point of great interest.

Schroeder (2: p. 42) has pointed out a character of colloids that has much of interest to the plant physiologists. He finds that a gelatin gel is in equilibrium with a saturated atmosphere when it contains about 40 per cent of its dry weight in water

1. This interpretation is quite different from that given by Klebs.
2. Here some will contend that turgor pressure rather than hydration of colloids is the determining condition.

and with liquid water when it contains about 1100 per cent. If gelatin fully imbibed in a saturated atmosphere, is placed in water a rapid absorption occurs and the liquid water equilibrium is finally approximately reached. The reverse process takes place when a gel fully imbibed in liquid water is placed in a saturated atmosphere. Filter paper absorbs about equal amounts from saturated atmosphere and water. This character of gelatin and other gels is not certainly explained physically, but that does not concern the biologist so much as the question of whether the living body behaves similarly. Martin (24 and unpublished work) has found an exact counterpart of this behavior of gels in the pollen of alfalfa. The pollen has a very narrow range of water supply necessary for its germination. This is the main factor in the uncertainty of seed production—a matter of considerable economic significance in the United States. In distilled water the grains swell rapidly and burst. In a saturated atmosphere they germinate rather abundantly; but will not germinate in an atmosphere appreciably below the point of saturation. A number of experiments indicate that the final water equilibrium is an important factor here, although the rate of water absorption is likely of some significance. Shull (unpublished work) has found for several sorts of seeds that they contain much more water when in equilibrium with distilled water than when in equilibrium with saturated atmosphere.

If the entire plant acts like a piece of gelatin it should transpire to a saturated atmosphere when its lower end is in water. Dixon (25) claims that this occurs. This character of gels may be acting along with raised temperature due to absorption of radiant energy in maintaining transportation in plants of tropical rainy regions. It is a common thing in plant physiology to grow what are naturally soil or water roots in a saturated atmosphere and assume that they are in a normal condition. Aside from the rate of water absorption we have this character of gels raising a question as to the amount capable of being absorbed. Every worker in plant physiology has observed peculiar characters in roots grown in saturated atmosphere, such as reduced rate of elongation and profusion of root hairs. This gel character of plants may also play a part in guttation.

V DIFFUSION IN A COLLOIDAL MEDIUM

Peculiar diffusion and precipitation phenomena occur in colloidal substrata. Küster (26) attempts to relate these causally with the most diverse features of plant anatomy. His point of

departure is the Liesegang ring system. This concentric ring system is produced in a few hours after placing a droplet of 80 per cent $AgNO_3$ on a 5-10 per cent gelatin plate bearing one per cent $K_2Cr_2O_7$. The rings consist of Ag_2CrO_4 and become more definite and more distinct from each other as the distance from the drop increases. The explanation of this phenomenon is still in question, although it may be due to the colloidal substratum making possible great supersaturation before the labile equilibrium is reached. The bands formed in gelatin in capillary tubes show definite rhythm and polarity. Aside from the $Ag_2 CrO_4$ bands there are others caused by impurities in the gelatin which Küster terms small rhythms in contract to the great rhythms of $Ag_2 CrO_4$. Contact with the dish in contrast to free gelatin, tensions, pressures and many other conditions, produce a great variety of precipitation figures. In fact patterns can be produced that resemble closely all the various structures appearing in mottled leaves, in the arrangement of vascular elements of plants and the markings of tracheae. Küster emphasizes the fact that the pattern differentiation of $Ag_2 CrO_4$ precipitate shown in the gelatin plate is a self differentiation occurring under constant environmental conditions. This is taken to show that similar periodic or rhythmic structural changes in the cells may be independent of rhythm in the environment, a matter of self-differentiation. The work also indicates the possibility of separating such differentiation from vitalistic peculiarities. The fact that a simple diffusion process in gelatin gives complex polarized precipitation patterns leads the author to conclude that perhaps a complex pattern in the organism may likewise be referred to a simple diffusion process in a colloidal matrix rather than explained by appeal to complex regulative action of living protoplasm.

Rhythm in plant activity is held by many to be generally related to environmental rhythm. Others feel that rhythm is a necessity of the very nature of protoplasmic activity; activity must be followed by rest. An examination of the facts that Küster offers shows the possibility of rhythms in the organism independent of the inscrutable features of protoplasm. In short, internally determined rhythms may be matters of relatively simple physical and chemical laws. Bringing this third possibility of structural rhythm and polarity into prominence is the great contribution here. The work really has not explained in terms of process of formation a single plant or animal structure.

If the explanation of Ostwald mentioned above is correct, it means that a colloidal medium of the type of a gel favors

the maintenance of supersaturation, or of a metastable equilibrium. Likewise it seems to favor supercooling as does any capillary system. This last feature of colloids is claimed to be of importance in protecting the organism against death from low temperatures (1: pp. 50, 58, 27). The full discussion of this point, pro and con, would lead us, however, too far away from the main topic under consideration. A colloidal medium then seems to favor these two "Uberschreitungserscheinungen," supersaturation and supercooling, and perhaps through these explain certain behavior of organisms.

VI ENZYMES AS COLLOIDS

Enzymes which play the main role in the metabolism of living organism, have many characters indicating their colloidal nature. They are readily adsorbed by fine suspensions or other colloids. This adsorption is probably due in part to their surface tension activity, and in part to their electrical characters. In the first instance they show themselves closely related to the hydrophyllous colloids. In the second they manifest weak suspensoid characters (2: pp. 95-127).

Even the strongest argument against their colloidal nature —the fact that they never have been prepared in a pure state and that we therefore do not know their true nature—is an argument favoring it also, for it is an outcome of high adsorption capacity.

Grüss was able to separate the various enzymes of a plant organ by placing a drop of its juice on a stretched filter paper. As the drop spreads the enzymes arrange themselves in rings about its center in order of ease of adsorption by the paper. That the electrical charge of the enzyme particle is sometimes a factor in its adsorption is shown by the following reactions: kaolin, a negative suspension, will not adsorb invertase, a negative colloid, but *tonert*, a positive suspension, adsorbs invertase readily. Kaolin will adsorb malt diastase only if the diastase is acid in reaction, or is a positive colloid. In a neutral medium malt diastase, like trypsin, pepsin, and ptyalin, is nearly amphoteric, so the adsorption of all is more a matter of surface tension. Filtering of enzymes through charcoal or repeatedly through filter paper lowers their activity due to adsorption by the filter. The colloidal nature of enzymes has been called into play as a means of explaining their retention within the living cell. Hoffmeister believed their colloidal character prevented them from diffusing through membranes generally and especially through

protoplasmic membranes. On this basis he conceived that they were not only held within the cell, but also localized within the separate compartments of the multivacuolate protoplasm, as he pictured it. It has been shown, however, that enzymes are very highly dispersed colloids and that they diffuse readily through 10 per cent gelatin and Ruhland (13) believes through cell walls and protoplasm generally. This author thinks retention within the cell is due either to adsorption or more likely to actual chemical union with the protoplasm. He believes that this also accounts for the localization of enzymes within the cell.

In many of their activities enzymes behave like colloids. The question has often been raised whether their main function is a typical colloidal reaction or more of the nature of reactions in molecular solutions. The evidence generally is in favor of the second. In the first case diffusion should play the main role and the speed coefficient for 10°C rise in temperature should not exceed 1.25. For lipase, invertase, catalase, and tryosonase the coefficient is about 1.5, but for most enzymes it is from 2 to 3. Where the coefficient is as low as 1.5 diffusion between the two phases of the system (aided by increased Brownian movement of the enzymes and reduced viscosity of the medium) may be the main rate determining process; but where the coefficient lies between 2 and 3 the rate is probably determined by a reaction typical of homogeneous systems. The action of enzymes is, however, very complex, involving adsorption by the substratum and often by products of their action, and many other disturbing factors. As a consequence we are far from a quantitative statement of the kinetics of enzymes.

VII IMMUNITY BODIES AS COLLOIDS

In general when the physiological significance of colloids is discussed the characters and behavior of immunity bodies are used as illustrations. These show much in common with enzymes and many of the questions concerning the colloidal nature of the one has been asked and answered similarly for the other. Space does not permit the discussion of the colloidal characters of this group of substances and besides an excellent statement can be found in many texts (1, 2, 28).

VIII SOME COLLOIDAL PHENOMENA OF SOILS

There is a large number of reactions in the soil that are colloidal in nature and of great interest to the plant physiologist. The soil is the environment of approximately one-half

of each land plant and, so far as many processes are concerned, the more interesting, if the less well understood, half. Flocculation, a process by which clay soils are rendered more penetrable and given a better oxygen supply, is a typical reaction between suspensoids and suspensions and electrolytes. It is well illustrated in delta formations at the mouths of rivers where the silt and clay constituents of the fresh water are brought into contact with the salts of the sea water and flocculated. The effect here is mainly due to the cations of the salt acting on the negatively charged soil particles. Deflocculation, brought about by the addition of excess of flocculating salts, is a well known reaction of suspensions and suspensoids included under the term peptisation (1: p. 293-295).

The dissolution and removal from the soil of lime carbonate, its natural sweetener or neutralizer, and the final accumulation of acid in it, is in part at least due to flocculation. The positive ions of the inorganic salts are absorbed by the organic and inorganic negative soil particles and the latter are flocculated, leaving free in the soil the strong inorganic acids corresponding to the negative ions of the salt. The soil particles thus flocculated may be of microscopical size, or suspensions, or of ultramicroscopical size—true colloids; but the principle of the reaction is the same in either case. Flocculation, in part at least, explains the mysterious humic acids of the soils that have been so much discussed without certain identification and so far as it does account for the acidity shows that the acids are largely not organic but inorganic.

Daikuhara (29) has lately brought evidence to show that the injurious effects of adding fertilizer salts to many soils of Japan and Korea, poor in lime, are due to the fertilizer salts freeing complex acid salts of aluminium and iron from adsorbed condition on the colloids of the soil. If lime accompany the fertilizers very beneficial effects results from them. He implies that the same may be true in America where acid soils are so prevalent.

Litmus paper as a qualitative test for soil acidity has its short-comings in the differential adsorption of the two ions of the organic salts of the litmus by the suspensions and suspensoids of the soil on one hand, and by the colloids of the paper on the other—typical adsorption processes of suspensoids. The common quantitative tests for soil acidity are rendered unsatisfactory on similar grounds (30).

Of course, no one will claim that the total loss of lime carbonate from the soil (about 800 lbs. per acre per year) along

with the final assumption of the acid character by the soil is due solely to the acids set free by the flocculation of organic and inorganic suspensoids of the soil. There are a great number of acid forming processes going on in the soil; carbon dioxide production of the respiration and fermentation of soil organisms and nitric acid production by the nitrifying processes (oxidation of ammonia salts to nitric acid by nitrosomonas and nitrobacter) may be mentioned as two important ones.

As one passes from the coarse sands to the finer clay he finds a continual rise in the specific surface presented by the soil—that is, a continual rise in the total surface of the soil particles per unit volume. The high specific surface of the finer soils is due in part to particles of micronic or microscopic size, but in large part to the ultramicroscopic or submicronic particles—soil colloids, inorganic and organic. The great specific surface developed in fine soils, especially those with considerable colloidal constituents brings about much adsorption or concentration of dissolved and suspended substances on the surface of the soil particles. This surface accumulation is due in part to electrical effects typical of suspensoids and in part to the surface tension active substances in accordance with the Gibbs-Thompson law. Whatever the cause of these surface concentrations the result is that many new reactions are set up between the concentrated materials themselves and between them and the soil particles. We often speak of sandy soils being poor in plant nutrients, while clays are rich. This is largely due to the surface phenomena and the reactions resulting from them.

In fact any good soil shows many of the characters of a colloidal medium, or is essentially a colloid, as is well expressed by a quotation from Russell's Monograph (31) on Soil Conditions and Plant Growth, "It is a mistake to suppose—and this point cannot be too strongly emphasized—that the medium on which the soil organisms live, and which is in contact with the plant roots, is the inert mineral matter that forms the bulk of the soil. Instead, the medium is the colloidal complex of organic and inorganic compounds usually more or less saturated with water, that envelops the mineral particles. It is therefore analogous to the plates of nutrient jelly used by bacteriologists, while the mineral particles serve mainly to support the medium and control the supply of air and water and, to some extent, the temperature."

IX TOPICS IN COLLOIDAL CHEMISTRY AND THEIR BEARING UPON PHYSIOLOGY

Almost any topic commonly discussed under hydrophyllous colloids can also be discussed in important biological relations. Let us select three of a considerable number of such topics for brief consideration: hysteresis, protective action of hydrophyllous colloids, and the anion series of alkali salts.

Hysteresis, or spontaneous ageing changes, so common in colloids has many points of physiological interest. These are well illustrated in vitro by the slow or rapid flocculation of any colloidal solution; by the reaction between immune bodies becoming irreversible with time and by changes in the vapor tension of gels, continuing for weeks or months after their formation. No doubt many changes in the living or non-living parts of the organism fall under this head.

Seeds in dry storage lose their power to germinate gradually—some even after a year and others only after a century and a half. This is likely due to slow coagulation of embryo proteins (32). Seeds of Amaranthus retroflexus will not germinate when harvested, but will do so after a month or two of storage under uniform conditions. This is a result of spontaneous ageing changes in the gels of the seed coats. Such ageing changes have also been observed in spores. Heating the oat coleoptile to 39°C for one hour lowers the rate of photo-perception at 20°C fourfold. After four hours at 20°C the old speed is regained. This recovery has been interpreted as a matter of hysteresis in cell colloids rather than elimination of poisons formed at the higher temperatures, although the latter interpretation is possible The main virtue of classifying some of the spontaneous changes in the organism under the term hysteresis is not that it furnishes in itself an explanation of them. It takes these problems out of their connection with vital qualities and places them on the basis of a colloidal substratum capable of physical and chemical study.

Protective colloids are colloids of the hydrophyllous type which have the character of forming a film about the particles of suspensions or suspensoids and preventing their flocculation. Blood serum often bears uric acid far above the saturation point. Albumins of the serum of the blood acting as protective colloids keep the droplets of uric acid in suspension. The droplets vary in size from amicrons to microns, depending upon the degree of supersaturation. The high content of calcium phosphate in milk is probably explained on a similar basis. Gall stones and bladder stones are in part due to short-

age of protective colloids for holding certain insoluble substances in suspension.

Hofmeister showed that certain anions of alkali salts decrease the amounts of water absorbed by gelatin gel, while others increase it. The sulfate, tartrate, citrate, and acetate anions cause shrinkage, while bromides, nitrates and rhodonates cause swelling. Starting with this determination a great amount of later work has led to a rather definite arrangement of the anions of alkali salts in relation to this as well as other characters of colloids and to a number of physical and chemical processes in homogeneous solutions (1: pp. 309-326). The following are interesting colloidal applications of this series. In salting out hydrophyllous colloids, the sulfate-tartrate end is most effective, while certain anions of the opposite end of the series cause dissolution. The same order holds in the productions of gels from sols. The cations show less range in effectiveness, but they too can be arranged especially in regard to precipitation of colloids, in definite order reversed, however, with a reversal in the charge. We generally consider tropic movements in plants, so far as their underlying causes and processes are concerned, as amongst the most complex of plant phenomena. Porodko (33) shows in a recent publication that the effectiveness of the anions of salts of alkali metals in producing positive chemotropism follows almost exactly this series: Tartrate> citrate> sulfate> acetate> chlorate> chloride> nitrate> iodide> cyanide. The effectiveness of their cations for positive chemotropism also approximated their effectiveness for the precipitation of colloids in an acid medium, thus: rubidum> caesium> potassium> lithium> sodium. Bromide does not cause positive chemotropism. These and a number of other facts discovered by Porodko indicate that dehydration or flocculation of colloids bears a fundamental relation to chemotropism. Work by Fischer and by Schley indicates similar significant relations between geotropic response and water absorption by colloids (12, 34). To date, however, the results on both chemotropism and geotropism in this line are only suggestive and open the possibility of attacking these complex phenomena of plants on a definite basis of the physics of colloids.

X CONCLUSIONS

In closing let us attempt to make a few summary statements: In discussing the topic colloidal chemistry in relation to biology, one faces a relatively new science with a still newer application to another science. The application to date

has been made only at occasional points and not consistently over the whole field. Hence the discussion takes more the nature of isolated illustrations than of a summary, but these illustrations bring into prominence a few very important facts and open up situations of great promise.

The living portion of the organism and many parts produced by it are in the main colloidal and in their behavior obey the laws of colloids. Rational explanations in this field cannot be expected when these basal facts are neglected.

Therefore many of the phenomena of the living organism and some of the phenomena of its environment, which entirely lack explanation on the basis of homogeneous systems, are common processes of colloidal systems.

Although at present the application of colloidal chemistry to biology offers much more of bright prospect and excellent promise than of accomplishment, it is certain that as the application progresses many processes that had to be included under the unexplained group of vital processes will find partial or complete elucidation on the basis of laws of colloids.

But even after colloidal chemistry consummates its possible accomplishments in biology, the vitalist will still have legs, although quite different legs, yet legs to stand upon.

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Papers on Water Supply

EXAMINATION OF DRINKING WATER ON RAILWAY TRAINS

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In order to determine the character of water furnished to the passengers on railway trains, 100 samples from water containers on trains have been collected and analyzed by members of the staff of the Illinois State Water Survey. Although the number of samples examined is small, the information obtained concerning the actual condition of the waters should be valuable in formulating practical standards. The samples were secured from trains at Champaign, Urbana, Kankakee and Chicago. It was thus possible to secure samples from cars coming from all parts of the country.

Of the 101 samples: Twenty-eight of the tanks were said to have been last filled at Chicago. Nine at Peoria. Eight at Centralia. Six at Detroit. Five at Cincinnati. Four at Indianapolis. Three at Kansas City, Mo. Two each at Memphis, Tennessee; Salamanca, New York, and New York City. One each at Boston, Massachusetts; Buffalo, New York; Champaign, Illinois; Dubuque, Iowa; Effingham, Illinois; Forrest, Ill.; Ft. Madison, Ia.; Ft. Wayne, Ind.; Grand Rapids, Mich.; Havana, Ill.; Lincoln, Neb.; Mason City Ia.; Mattoon, Ill.; Minneapolis, Minn.; Montreal, P. Q.; Nashville, Tenn.; Parsons, Kans.; Pittsburgh, Pa.; St. Louis, Mo.; St. Paul, Minn.; Sioux City, Ia.; South Bend Ind.; Springfield, Ill. Four were filled with bottled water from Hammond, La., one with bottled water from Waukesha, Wis. The water in five was of unknown origin. The majority of the samples, 57, were taken from coaches, 19 from sleepers, 8 from dining cars, 7 from smoking cars, 6 from parlor cars, 2 from tourist sleepers, and of 3 there was no record.

The analyses include both bacteriological and chemical examinations and an attempt has been made to make them as complete as possible when using 120 cc. samples for bacterial examination and one liter samples for the chemical tests.

METHODS OF ANALYSIS

The analyses have been made as far as possible in accordance with Standard Methods of Water Analysis of the American Public Health Association (1912) and all analyses made after May 1 include confirmations of *B coli* made in accordance with the recommendations of the Commission on Standards for Common Carriers in Interstate Commerce.

Ninety-nine samples were examined for turbidity. Of these 70 showed a turbidity less than 5 parts per million; 82 less than 10; 69 less than 15, and only 10 showed 15 or more. A turbidity below 10 would not make the water appear unattractive and it would seem not unreasonable to require a standard of 10 or less.

Ninety-nine samples were examined for color. Seventy-nine of the samples had a color less than 5 parts per million; 88 less than 10; 93 less than 20, and only 6 had 20 or more. A color requirement of 20 or less should be easy to meet and it would not be impossible to meet a requirement of 10 or less.

Ninety-nine samples were examined for residue. Of these 28 had a residue less than 50 parts per million; 36 less than 100; 75 less than 200; 84 less than 300; 90 less than 400; 95 less than 500, and only 4 above 500. The very low residues are undoubtedly due to the presence of melting ice in the coolers. The few samples containing more than 500 parts per million would indicate that a standard of 500 or less could easily be made.

Chlorine was determined in 99 samples. Of these 46 had less than 5 parts per million; 66 had less than 10; 75 had less than 15; 82 had less than 20; 90 had less than 25, and only 9 more than 25 parts per million. It should not be difficult to obtain a water containing less than 15 parts of chlorine per million and it should certainly be easy to obtain water containing less than 25 parts per million. In special cases where it is not possible to obtain waters with low mineral content, exceptions to the rule may be made. The same may be true also of residue, magnesium, sulfates, alkalinity and hardness.

Sixty-six were examined for magnesium. Of these 39 contained less than 10 parts per million; 51 less than 15; 60 less than 20, and only 6 more than 20 parts per million. In the large majority of cases, therefore, it should be easy to obtain waters containing less than 20 parts per million of magnesium. If the magnesium were all present as sulfate, 20 parts of magnesium would be equal to 100 parts of magnesium sulfate.

The alkalinity using phenolphthalein and methyl orange as indicators was determined in 99 samples. In only one case was a water found which was alkaline to phenolphthalein. A requirement that the alkalinity of phenolphthalein shall not be greater than one-half the alkalinity to methyl orange would be easy to fulfill and would guard against the use of water over treated with lime. Forty-three samples contained less

than 50 parts of alkalinity to methyl orange, 71 less than 100, 89 less than 200. Only 10 had an alkalinity of over 200, and only one of more than 300. A standard of 300 or less would be very easy to maintain and a standard of 200 or less would not be impossible.

The total hardness was determined on 64 samples. Of these 34 had a total hardness of less than 50; 45 less than 100; 57 less than 200. Only 7 had a hardness of more than 200, and but 2 a hardness of more than 300. A limit of 300 would be very easy to maintain and it should not be difficult to obtain waters containing less than 200.

Sixty-six waters were examined for sulfates. Thirty-six waters contained than 10 parts per million of SO_4; 42 less than 25; 54 less than 50; 63 less than 100, and only 3 more than 100. It should be apparently very easy to furnish waters having less than 100 parts per million of sulfates.

Ninety-nine samples were examined for iron. Eighty-six of these contained less than .5 parts per million of Fe; 94 less than 1.0; and only 5 had more than 2 parts per million. A standard of less than 1 part per million would be very easy to maintain and it would not be unreasonable to ask for .5 parts.

Sixty-six samples were examined for lead and copper. Fifty-six of these showed no trace of either metal; 7 contained .1 part per million; 2 contained .2, and 1 contained .3. It would not seem difficult to maintain a standard of less than .3 or even less than .1 part per million.

One hundred samples were plated on gelatin and the number of colonies counted at the end of 48 hours. Of these, 29 samples had less than 99; 16 samples from 100 to 499; 16 from 500 to 999; 9 from 1,000 to 1,000; 9 from 2,000 to 9,999, and 21 more than 10,000.

One hundred and two samples were plated on agar and incubated at 37½° for 24 hours. Forty samples showed less than 50 bacteria per cc; 7 from 50 to 99; 8 from 100 to 199; 14 from 200 to 499; 8 from 500 to 999; 10 from 1,000 to 1,999; 10 from 2,000 to 9,999, and 5 had more than 10,000.

While the large number of bacteria may consist for the most part of harmless forms, the results would indicate unsatisfactory conditions, either in the original water taken or in the conditions of storage and delivery.

The Commission on Standards have made no recommendation concerning the use of gelatin, but their standard of less

than 100 growing on agar would mean that 53 per cent of the waters examined were unsatisfactory.

One hundred and nine positive tests for gas formation were obtained in 67 samples examined after May 1. Ninety-one, or 83 per cent of these were shown by the confirmatory tests to contain *B. coli.*

Twenty of the 67 waters were shown to be unsatisfactory by both standard for *B. coli* and agar count of the Commission on Standards of Purity for Common Carriers. Four more did not conform to the *B. coli* standard alone and 24 more did not conform to the agar count standard, making a total of 49 of 67 samples or 73 per cent which did not conform to the standards set by the Commission.

While our methods differ from Creel (Hygienic Laboratory Bulletin 100, 43-57), the results judged by the *B. coli* standard are similar, showing that a better water is found on sleeping cars and parlor cars and the poorer water is found on coaches and smoking cars.

Mr. W. W. Hanford of the Illinois State Water Survey is making a study of the character of the water supplied to railway trains from points in Illinois. As time permits we expect to make more analyses of samples of water taken from trains. An improvement is to be expected as the railway officials are endeavoring to improve conditions as rapidly as possible.

Credit must be given to the members of the laboratory staff of the Illinois State Water Survey for the work which is described in this article.

(A table showing the results of the 102 analyses is published in the Journal of the American Water Works Association for March, 1915, and in Bulletin 12 of the Illinois State Water Survey.)

THE ARSENIC CONTENT OF FILTER ALUM USED BY ILLINOIS WATER PURIFICATION PLANTS

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INTRODUCTION

Specifications requiring arsenic free alum for water treatment by several European[1] purification plants suggested to us that it would be advisable to make determinations of the arsenic content of the filter alum used in the State of Illinois.

It is well known that products which are manufactured with the aid of commercial sulfuric acid quite generally contain more or less arsenic, depending upon the purity of the acid used. The poisonous character of arsenic compounds, even when present in small amounts, makes it of general interest and importance to have definite knowledge of the presence or absence of arsenic in any substance which enters directly or indirectly into foods or drinks. Sulfuric acid is used in the manufacture of filter alum and it is thus quite essential, particularly to those who are in public health work, to know whether arsenic in any considerable amounts is being added to drinking water in the process of purification with alum.

We have not been able to learn that anything has been done in this country to regulate the amount of arsenic in filter alum. The purification plants (at least in this State) have made no effort to obtain an arsenic free article. The manufacturers of alum keep more or less accurate records of the arsenic content of their product, but we have found no published records. We have found only one producer who advertises "arsenic free alum." Neither the government nor any of the States have promulgated legislation regulating this product, although there is a regulation concerning arsenic in other substances entering into foods. The government has set a limit for arsenic in coal tar dyes and in baking powder of one part in 700,000. This very low limit, particularly when it is considered that only relatively small amounts of these substances are used in food preparation, shows that considerable importance is attached to the presence of arsenic and its compounds.

Samples: In order that our results might be of greatest value by showing the condition of the alums as they are actually used, we obtained as many samples as possible directly from the various purification plants in the state. Twenty-six plants use alum in treating the water. The purpose of our investiga-

1. Jour. f. Gasbel: 1913 (Sept.)

tion was explained to the managers of each plant. They were asked to co-operate with us by furnishing a sample of the alum used, together with the name of the manufacturer or dealer supplying the same. Twenty-one of the plants very promptly complied with our request, and in nearly every case, expressed decided interest in the subject with a wish to know the results of our investigation. The specimens of alum were carefully sampled, ground and analyzed in duplicate by the following methods:

Methods of Analysis: The method used in obtaining most of the data given is a modified Gutzeit Method, developed by Claude R. Smith[1] in his work on coal tar dyes and other food constituents. The results obtained by this method were in several cases checked by the Marsh-Bezelius Method[2] and were found to agree. The Gutzeit Method has been investigated by others for quantitative work, and, when proper care is taken in the manipulation, has been found to give satisfactory results. The chief modification proposed by Smith is the use of paper sensitized with mercuric bromide in the place of mercuric chloride, which had previously been generally used. The bromide gives more permanent stains and the standards can be kept longer. The method depends upon the formation of a dark orange stain when the generated arsine is brought in contact with the sensitized paper. Under uniform conditions, the length of the stain varies with the amount of arsenic present. A series of standard stains prepared from known amounts of arsenic are used for comparison. A convenient series is made from 2, 5, 7.5, 10, and 15 micro milligrams. The amount of arsenic in the weight of alum taken is determined by matching the stain it produces with the standards; it is then a matter of simple calculation to determine the percentage arsenic content or the parts per million of arsenic. A one gram sample will contain as many parts per million of arsenic as there are micro milligrams of stain obtained. For example, if one gram of alum produces a stain which matches the 5 micro milligram standard stain, then that alum contains 5 parts per million. One part per million is equivalent to .0001 of one per cent. A stain representing between five and twenty-five milligrams gives the most satisfactory results. A stain between these limits can be obtained by varying the weight of alum used.

Experiments: Preliminary qualitative tests were run on several samples of alum that were in the laboratory. All were

1. U. S. Dept. Agr. Bur. of Chem., Circular No. 102.
2. U. S. Dept. Agr., Bur. of Chem., Circular No. 99.

found to contain arsenic, but apparently in rather small amounts.

The results from the samples obtained from the purification plants are given in a table. In all cases the arsenic is recorded as arsenic trioxide, As_2O_3. Five gram samples of the alum were used, as this amount gave stains best suited for comparison with the standards. Quincy and the Rock Island Arsenal each submitted samples from two different manufacturers, therefore twenty-three samples from twenty-one places were examined.

TABLE I.

ARSENIC AS As_2O_3 IN FILTER ALUMS USED IN ILLINOIS

City	Arsenic as As_2O_3		
	Pts. per mil	Percent	Gallons*
Cairo	1.6	.00016	3213
Carlinville	1.8	.00018	2856
Charleston	1.2	.00012	4283
Chicago and Rogers Park	1.4	.00014	3671
E. St. Louis and Granite City	.8	.00008	6425
Decatur	1.4	.00014	3671
Elgin	1.6	.00016	3213
Ft. Sheridan	1.2	.00012	4283
Hamilton	1.4	.00014	3671
Kankakee	.8	.00008	6425
Kenilworth	1.4	.00014	3671
Lawrenceville	3.0	.00030	1713
Macomb	1.6	.00016	3213
Moline	1.0	.00010	5140
Mt. Carmel	2.0	.00020	2570
Mt. Vernon	1.2	.00012	4283
Pana	1.2	.00012	4283
Quincy	1.0	.00010	5140
Quincy	4.0	.00040	1285
Rock Island	2.0	.00020	2570
Rock Island Arsenal	1.6	.00016	3213
Rock Island Arsenal	1.0	.00010	5140
Streator	3.4	.00034	1512

*Gallons of water containing a minimum medicinal dose of 2 mg. when the water is treated with 6 grains of alum per gallon, provided that all the arsenic remains in solution.

The results obtained by analyzing alum used in Illinois clearly show that arsenic in exceedingly small amounts is always present in filter alums. We find a minimum of 0.8 parts per million (.00008 per cent) and a maximum of 4.0 parts per million (.0004 per cent) of arsenic as As_2O_3 in the alum used by Illinois water purification plants. If a water were treated with alum containing the maximum amount of arsenic found at a rate of 6 grains of alum per gallon, an amount which is very seldom exceeded, and if all the arsenic were soluble and remained in the filtered water, since arsenic is not an accumulative poison, a person must drink 1285 gallons of the treated

water at one time to obtain a medicinal dose of 2 milligrams. From this it is readily seen that the arsenic content of filter alums used in Illinois is of no significance.

All alums used in this State are supplied by western manufacturers. Several samples have been obtained from the East. In some of these the arsenic content is much higher than that of the Illinois alums. This matter is being investigated further and will be reported later.

THE LONGEVITY OF *BACILLUS COLI* AND *BACILLUS TYPHOSUS* IN WATER

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It has long been known that in natural water there is a tendency of the intestinal bacteria to die out, but very little is known concerning the conditions which govern their death rate. The available data on the subject deal mostly with streams and reservoirs and are influenced by several variable conditions. Very few data are to be found dealing with pure cultures of bacteria and with known conditions of light, temperature, food supply, dissolved oxygen and the presence or absence of other micro organisms.

Most of the published data on the death rate of bacteria refer to death by drying or by disinfectants. The best work has been by Madsen and Nyman[1], Paul[2], Harriett Chick[3], and Eijkman[4]. Their results show a constant rate of death. When the logarithms of the number of bacteria present are plotted against the time, a fairly straight line results. This is the curve of the monomolecular law and was first noted by Madsen and Nyman and lated used by Harriett Chick, who determined constants for all of her data.

All of our work was done with pure cultures of *B. Coli* and *B. typhosus*, kept constantly fresh and vigorous by daily transfers in one per cent lactose broth. When the culture was to be used, smears were made on agar plates and grown for 12 hours, then suspended in sterile water and suitable portions of the suspension used. This method is better than that of using broth cultures for inoculation as only a minimum amount

1. Madsen and Nyman. Beit. f. Hyg. 57, 388, 1907.
2. Paul. Biochem. Zeit., 29, 202 and 249, 1910.
3. Chick. Jour. of Hygiene, 10, 237, 1910.
4. Eijkman, Verslag. der kon. Akad. Wetenschaffen, V. 21, 1, 510, 1912.

of food material is transferred.

All samples of water used were sterilized before inoculation, the samples kept in hydrogen and nitrogen being in filter flasks, the gas entering through the side tube and escaping through a capillary tube at the top. The other samples were kept in Erlenmeyer flasks.

Table I gives the results of *B. coli* in several waters. The constant k is obtained from the formula:

$$k=\frac{1}{t} \qquad \ln\frac{N}{n}$$

t being time, ln the natural log., N the original number of bacteria and n the final number.

TABLE I.

Death rate of B. coli in various waters.

	Redist.	N Free		Dist. H_2O		Well Water		Tap Water U. of I.
Hours	Count		K	Count	K	Count	K	Count
0	1,104,000			212,000		1,920,000		1,500,000
2	4,000	2.809)		19,000	(1.205)	500,000	.672	2,209,000
12	1,000	.583		16,000	.215	3,000	.528	1,360,000
24	200	.358		200	.290	200	.381	1,280,000
48	5	.256		3	.159	1	.301	
72								2,650,000
96								2,400,000
6 days								730,000
37 days								
Average			.399		.221		.470	

The deep well water was quite high in mineral matter, especially nitrates, but contained only a trace of organic matter.

Table II shows the effect of absence of oxygen on *B. Coli*. The cultures were incubated in atmospheres of nitrogen and hydrogen.

TABLE II.

B. Coli in Air, Nitrogen and Hydrogen

	1						2					
	A		N		H		A		N		H	
Time	Count	K	Count	K	Count	K	Count	K	Count	K	Count	K
0	4,000,000		4,000,000		4,000,000		2,800,000		3,350,000		2,700,000	
1.5	3,100,000	(.169)	2,880,000	.219	2,300,000	.368	1,460,000	.434	2,750,000	(.131)	2,000,000	.200
6	450,000	.364	1,760,000	.137	760,000	.277	57,000	.649	2,250,000	.066	385,000	.324
11	50,000	.398	530,000	.184	28,000	.451	10,000	.469	1,650,000	.059	170,000	.230
24	600	.352	95,000	.155	4,500	.271	3,000	.285	520,000	.077	10,000	.233
36	7	.368	50,000	.121	1,300	.223	1,500	.209	320,000	.065	3,600	.184
48	0	.317	30,000	.102	0	.317			160,000	.063	700	.172
72							960	.111	64,000	.055	400	.108
Aver.		.360		.153		.318		.359		.064		.207

TABLE III.

B. typhosus at different temperatures

	1						2					
	8°		20°		37°		8°		20°		37°	
Time	Count	K	Count	K	Count	K	Count	K	Count	K	Count	K
0	195,00		118,000		110,000		93,000		83,000			
2	10,000	1.485	7,500	1.377	500	2.701			10,000	1.057		
4	2,100	1.035	500	1.365	20	1.806	2,200	.936	800	1.160		sample
6	1,325	.832	280	1.007	0	1.934	725	.809	1,550	.663		
8	950	.665	230	.779			300	.718	370	.676		contaminated
10	500	.596	150	.666			265	.586	300	.562		
12			30	.689			130	.548	90	.569		
14	470	.430	30	.591			60	.524	35	.555		
24	60	.336	2	.458			10	.381	0	.471		
Aver.		.768		.866		2.147		.643		.714		

Nitrogen free water was used for the temperature tests. The constants for air are very good but those for nitrogen and hydrogen are variable but always less than for air showing a slower death rate. No reason for this variation was found.

Only a small amount of work was done with *B. typhosus.* The results obtained were very erratic. The technic was the same as was used for *B. Coli.*

It was impossible to obtain good, uniform constants within each set of counts. The averages of different sets were so far apart that no comparison was possible. One possible explanation is that the stock cultures were kept at 20° and the agar plate which was used to furnish the suspension was incubated at 37° for 12 hours. This sudden change may have weakened some cells to such an extent that uniformity was destroyed.

In general, the *B. typhosus* results was similar to those of Whipple and Mayer[1] and Ruediger[2].

The death rate was higher in nitrogen than in air and the rate increased with a rise in temperature.

CONCLUSIONS

Cultures can be kept uniform for several weeks by daily transfers and by keeping them at the same temperature.

In pure, natural water and in redistilled water *B coli* and *B. typhosus* die from starvation in the gradual regular manner observed in other causes of death.

Within the limits of temperature studied, 8° to 37°, the rate of death increased with a rise in temperature.

The death is similar to a chemical reaction and follows the monomolecular law.

The presence of mineral matter has no apparent effect on the organisms.

The presence of oxygen under starvation conditions seems to be harmful to *B. coli* and beneficial to *B. typhosus.*

This work was carried on under the direction of Doctor Otto Rahn of the Bacteriology Department of the University of Illinois and was done in the laboratories of the Illinois State Water Survey.

1. Whipple and Mayer. Public Health Reports, Vo. 32; Part 2, 76, 1905.
2. Ruediger. Am. J. Pub. Health, 1, 6, 411, 1911.

MANGANESE IN ILLINOIS WATER SUPPLIES

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The presence of manganese in water supplies, except in concentrations so low as to be insignificant, has always been considered rather unusual. This is true particularly in the United States. In Europe, however, manganese in water supplies has been encountered in a number of instances.

R. S. Weston[1] cites some twenty ground water supplies in this country and in Europe, which have been reported as containing manganese:

Locality	Manganese (parts per million)
Arad, Hungary	present
Babylon, N. Y.	0.07
Bayshore, N. Y.	0.37
Berlin, Germany	present
Björnstorp, Sweden	3.4-43.4
Brunswick, Germany	present
Breslau, Germany	trace—110
Calverton, N. Y.	.30
Halle, Germany	1.50
Hamburg, Hofbrünnen	.45
Hanover, Germany	present
Patchogue, N. Y.	.20
Reading, Mass.	.004-0.56
Stargard, Germany	present
Stettin, Germany	5.22
Superior, Wisconsin	.12
Shrewsbury, Mass.	.10

The first instance in this country where manganese was found in sufficient quantity to cause trouble was in the case of the well water supply of a New England mill in 1898[2]. This supply was abandoned because of the high manganese content.

Some sixty-two springs in the United States are mentioned by W. P. Mason[3] as having been reported to contain manganese. Mason states, however, that in nearly half of these the element occurs in traces, and only in seven instances does the amount equal or exceed the content of 4.5 parts per million which he found in the case of a mineral spring at Excelsior Springs, Mo.

Manganese determinations are not made in the general routine work of water laboratories, because the occurrence of the element in water has been considered rather unusual.

1. Trans. Am. Soc. C. E. 64, 124.
2. Trans. Am. Soc. C. E. 64, 124.
3. Chem. News, 61, 123.

Locality	Manganese	Iron	Residue	Source	Remarks
Abingdon, Knox	.00	.0	1323	1350 ft. well	St. Peter
Aledo, Mercer	.00	.0	2078	3165 ft. well	Potsdam
Amboy, Lee	.00	1.4	450	2400 ft. well	Potsdam
Anna, Union	.00	.0	347	650 ft. well	Limestone
Anna State Hospital, Union	1.3-7.5*	.1-.6*	170-214*	Impounding reservoir	
Anna State Hospital, Union	.05-.2*	1.0*	290*	Wilson Creek	
Arlington Heights, Cook	.00	.2	751	125 ft. well	Glacial drift
Arthur, Moultrie	.00	2.2	491	75 ft. well	Glacial drift
Aurora, Kane	.00	.4	2198	2000 ft. well	Potsdam
Barrington, Cook	.00	.4	397	325 ft. well	Limestone
Bellwood, Cook	.00	1.0	546	1400 ft. well	St. Peter
Belvidere, Boone	.00	.0	511	1800 ft. well	Potsdam
Benton, Franklin	.12	3.5	282	Impounding reservoir	
Bloomington, McLean	.00	.1	768	100 ft. wells	Glacial drift
Blue Island, Cook	.00	.2	1246	1800 ft.-2000 ft. wells	Potsdam
Braidwood, Will	.08	.3	492	20 ft. wells	
Byron, Ogle	.00	.0	288	2000 ft. well	Potsdam
Cairo, Alexander	.00	.1	240	Ohio river	
Carbondale, Jackson	.00	.4	3395	610 ft. well	
Carbondale, Jackson	.00	.1	2198	410 ft. well	
Carbon Hill, Grundy	.00	.8	1295	1800 ft. well	Potsdam
Chadwick, Carroll	.00	.3	399	600 ft. well	St. Peter
Chenoa, McLean	.00	1.1	1298	2100 ft. well	
Chicago, Cook	.00	.0	151	Lake Michigan	
Chillicothe, Peoria	.00	.3	504	35 ft. well	Alluvial
Crystal Lake, McHenry	.00	.06	444	32 ft. well	
Cuba, Fulton	.00	.4	2548	1765 ft. well	St. Peter
Danvers, McLean	.00	1.6	548	211 ft. well	
Danville, Vermillion	.00	.0	454	Vermilion River	
Decatur, Macon	.00	.0	375	Sangamon River	
DuQuoin, Perry	1.50	.2	1066	30 ft. well	
DuQuoin, Perry	.24	.1	1160	Abandoned coal mine	
E. Dubuque, Jo Daviess	.00	.2	278	940 ft.wells	Potsdam

Locality	Manganese	Iron	Residue	Source	Remarks
Edwardsville, Madison	.50	1.8	252	55 ft.-80 ft.wells	Alluvial drift
Effingham, Effingham	.00	.1	235	Little Wabash River	
Elgin, Kane	.10	3.2	377	1300 ft. wells, (Nos. 2, 4)	St. Peter
Elgin, Kane	.00	.4	493	1300 ft. well (No. 3)	St. Peter
Elgin, Kane	.08	.8	380	2000 ft. well (No. 1)	Potsdam
Elmwood, Peoria	.00	.7	1488	1300 ft. wells	St. Peter
Eureka, Woodford	.08	3.0	719	90 ft. wells	Glacial drift
Fairfield, Wayne	.00	.4	905	200 ft. wells	
Farmington, Fulton	.00	.3	1595	1465 ft. wells	St. Peter
Flora, Clay	.08	.0	145	240 ft. wells	
Forest Park, Cook	.00	.0	530	1668 ft.-2015 ft. wells	Potsdam
Forreston, Ogle	.00	.0	610	300 ft. wells	Limestone
Galesburg, Knox	.00	.0	1515	1240 ft. wells	St. Peter
Genoa, DeKalb	.00	.0	315	1500 ft. wells	St. Peter
Gibson City, Ford	.04	.1	320	55 ft. wells	Glacial drift
Grand Ridge, LaSalle	.12	.8	328	196 ft. wells	Glacial drift
Greenup, Cumberland	.00	.05	681	Embarrass river	
Greenview, Menard	.50	1.0	655	80 ft. well	Glacial drift
Hamilton, Hancock	.00	.0	274	Mississippi River	
Havana, Mason	.08	.0	202	75 ft. wells	Alluvial drift
Henry, Marshall	.00	.0	520	1355 ft. wells	St. Peter
Highland Park, Lake	.00	.05	140	Lake Michigan	
Hinckley, DeKalb	.00	.7	340	675 ft. wells	St. Peter
Ipava, Fulton	.00	.0	2977	1575 ft. wells	St. Peter
Jacksonville, Morgan	.00	1.7	515	#1 well	
Jacksonville, Morgan	.00	2.0	424	#4 well	
Jacksonville, Morgan	.00	1.8	372	#5 well	
Jacksonville, Morgan	.00	1.6	1041	Morgan Lake	
Jerseyville, Jersey	.00	.1	328	1542 ft. well	St. Peter
Kankakee, Kankakee	.20	.1	426	Kankakee River	
Keithsburg, Mercer	.16	.3	1262	50 ft. well	
Lacon, Marshall	.00	.0	400	50 ft. well	Alluvial drift
LaHarpe, Hancock	.12	10.0	515	43 ft.-63 ft. well	Glacial drift

Locality	Manganese	Iron	Residue	Source	Remarks
Lawrenceville, Lawrence	.00	.1	1054	Embarrass river	
Leland, LaSalle	.00	4.8	337	230 ft. well	
Lena, Stephenson	.00	.0	497	600 ft. well	St. Peter
Lexington, McLean	.00	1.0	400	115 ft. well	Glacial drift
Mansfield, Piatt	.04	2.1	390	214 ft. well	Glacial drift
Manteno, Kankakee	.00	.4	678	60 ft. well	Limestone
Marengo, McHenry	.04	.1	392	14 ft. well	
Marion, Williamson	.04	.6	1801	#1 700 ft. well	Limestone
Marion, Williamson	.00	.4	1110	#3 700 ft. well	Limestone
Marion, Williamson	.04	.2	1127	#4 700 ft. well	Limestone
Marion, Williamson	.05	.2	1562	#6 800 ft. well	Limestone
Marion, Williamson	.06	.3	1535	#7 960 ft. well	Limestone
Matteson, Cook	.04	4.0	713	283 ft. well	Limestone
Millstadt, St. Clair	.20	.5	339	600 ft. well	
Minonk, Woodford	.00	.2	2337	1765 ft. well	Potsdam
Morris, Grundy	.00	.0	434	650 ft.-800 ft. wells	
Morrison, Whiteside	.00	.5	293	2048 ft well	Potsdam
Mt. Carmel, Wabash	.00	.05	730	Wabash river	
Mt. Morris, Ogle	.00	.1	500	500 ft. well	Limestone
Mt. Vernon, Jefferson	.12-.8*	.1*	215-367*	Impounding reservoir	
Mt. Vernon, Jefferson	.02		155	Casey Fork	
N. Crystal Lake, McHenry	.00	.3	344	285 ft. well	Limestone
Olney, Richland	.04	.7	145	Fox River	
Oregon, Ogle	.00	.8	285	1600 ft. well	St. Peter
Pecatonica, Winnebago	.00	.1	336	20 ft. well	Limestone
Peoria, Peoria	.16	.0	394	#1 60 ft. well	Alluvial drift
Peoria, Peoria	.44	.0	303	#2 60 ft. well	Alluvial drift
Peoria, Peoria	1.6	.05	302	#3 60 ft. well	Alluvial drift
Peoria, Peoria	.75	.8	270	#4 60 ft. we'l	Alluvial drift
Peoria, Peoria	.75	.6	289	#5 60 ft. well	Alluvial drift
Peoria, Peoria	.08	.0	413	#7 90 ft. well	Alluvial drift
Peru, LaSalle	.00	4.0	1730	1500 ft. well	St. Peter
Pontiac, Livingston	.08	.05	557	Vermilion river	

Locality	Manganese	Iron	Residue	Source	Remarks
Quincy, Adams	.00	.1	250	Mississippi river	
River Forest, Cook	.03	.1	452	1000 ft. wells	St. Peter
Riverside, Cook	.04	.2	891	2000 ft. wells	Potsdam
Roanoke, Woodford	.06	.9	900	30 ft. wells	Glacial drift
Rochelle, Ogle	.00	.1	337	1026 ft. wells	St. Peter
Roseville, Warren	.00	.0-.6	566-1047	1260 ft. wells	St. Peter
Rushville, Schuyler	.24	.2	362	20 ft. wells	Alluvial drift
San Jose, Mason	.08	.0	539	105 ft. wells	
Sheffield, Bureau	.20	.1	505	50 ft. wells	
Springfield, Sangamon	.6	2.0	325	45 ft. wells	Alluvial drift
Springfield, Sangamon	.2	.0	345	Sangamon river	
Spring Valley, Bureau	.00	.1	770	1400 ft. wells	St. Peter
Steger, Will	.00	1.0	465	318 ft. well	
Sycamore, DeKalb	.00	2.2	340	905 ft. well	St. Peter
Tolono, Champaign	.00	1.8	647	140 ft. well	Glacial drift
Toulon, Stark	.00	.01	1147	1465 ft. well	St. Peter
Trenton, Clinton	.00	.3	980	235 ft. well	
Utica, LaSalle	.04	.5	444	225 ft.-350 ft. well	Potsdam
Villa Grove, Douglas	00	.0	1022	235 ft. well	Glacial drift
Warren, Jo Daviess	.00	.1	379	700 ft.-875 ft. wells	St. Peter
Washington, Tazewell	.00	2.4	367	80 ft. -90 ft. wells	Glacial drift
W. Chicago, DuPage	.00	.8	405	322 ft. well	Limestone
Woodstock, McHenry	.00	2.6	403	85 ft. well	
Wyoming, Stark	.00	trace	1047	1557 ft. well	St. Peter

*These figures represent the limits of a number of determinations made at different intervals.

In April, 1911, the attention of the Illinois State Water Survey was called to a serious incrustation which had formed in the city water mains at Mt. Vernon, Illinois.* As a consequence, the pressure had become greatly reduced, and in some places complete stoppage of service pipes had occurred. An examination showed that the incrustation contained a large amount of manganese dioxide. The original water contained 0.7 parts per million of manganese. Later, water supplies in other cities were found to contain manganese. Consequently it seemed advisable to examine samples of water from sources which would be representative of typical supplies in order to obtain further information on this subject.

The results thus far obtained from the examination of the water supplies of the state are shown in the table. The amounts of manganese, iron, and residue on evaporation at 180°C are given, with the locality, the depth of well and the geological stratum penetrated. The words, St. Peter and Potsdam, refer to the series of sandstones known under these names. The samples were in all cases taken at the original sources, and not from the city taps.

One hundred and twenty-three waters from one hundred and three different cities were examined. The results show that the supplies of fifteen of these cities contain more than 0.1 parts per million of manganese, the average of the fifteen being about 0.4 parts per million. It is apparent therefore, that manganese is not unusual in the water supplies of Illinois.

No manganese was found in ten of the waters from the thirteen wells which penetrate the Potsdam sandstone. The remaining three contained very small amounts, 0.8 parts per million in a well at Elgin, .04 at Riverside, and .04 at Utica. No manganese was found in twenty-three of the waters from twenty-five wells which reach the St. Peter sandstone. The other two contained small amounts, .10 parts per million in water from a well at Elgin, and .03 parts in a well at River Forest. The two wells at Elgin which show the high manganese content are cased to a depth of less than 100 feet, and may be drawing water from upper strata. Manganese, then is not usually found in waters from deep wells in the sandstones.

Ten of twelve samples examined from wells in alluvial drift contained manganese. The average content of the ten was .52 parts per million. Manganese is, then, very frequently present in wells in alluvial drift.

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*Univ. of Ill. Bull., Waterway Survey Series No. 10, 52-57, 57-65. Proc. Ill. Water Supply Assn. 1912, 202-8, 209-12.

The three samples from impounding reservoirs in southern Illinois all contained more than 0.1 part per million of manganese. One of these contained as much as 7.5 parts per million, on one occasion, the amount varying with the rainfall in a surface water of this character. These reservoirs are fed by small streams and springs. The figures indicate that they frequently contain manganese.

No apparent relation exists between the manganese content, iron content and mineral content as indicated by the total residue on evaporation.

The manganese content of water supply is important from the practical standpoint, on account of the objectionable properties of manganese waters. In many respects they are similar to waters which carry iron. They form black stains on white plumbing fixtures and they turn fabrics which are washed in them a yellow color. They cause serious trouble from incrustation due to the separation of manganese dioxide. At the Anna State Hospital the use of a manganese bearing water has caused a hydrotherapy room, fitted with white enamel, tile walls and fixtures, to become seriously stained.

In conclusion, it may be said that the question of manganese content should not be overlooked in the selection of a water supply in Illinois.

This work was carried out under the direction of Professor Bartow, to whom the writer wishes to express his thanks. The subject is being studied further with reference to the removal as well as the further occurrence and method of determination of the element.

A COMPARISON OF METHODS FOR DETERMINING DISSOLVED OXYGEN IN WATER AND SEWAGE

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Dissolved oxygen determinations are of great value in the control of sewage disposal plants and as an index of the purity of the water in streams. Accuracy is necessary, but ease of manipulation is also of importance. Although numerous methods have been proposed, few have survived the tests of practicability and accuracy. In the last report of the Committee of the American Public Health Association on Standard Methods of Water Analysis, the Winkler method has been chosen as the standard. The Levy method is an optional method of the committee on standard methods of the American Public

Health Association, and has been used to a certain extent, but has the disadvantages of requiring special apparatus and a blank determination in each case. These two methods are practically the only ones in use in this country. A brief description of the chemistry of each method follows.

In the Levy method the sample is collected in a special pipette, into which is introduced an accurately measured quantity of ferrous ammonium sulfate ($FeSO_4(NH_4)_2SO_4$); a solution of sodium hydroxide (NaOH) is then added; ferrous hydroxide ($Fe(OH)_2$) is formed and part of this is then oxidized to ferric hydroxide ($Fe(OH)_3$) by the dissolved oxygen present. Sulfuric acid (H_2SO_4) is then added and the remaining ferrous sulfate ($FeSO_4$) is titrated with standard potassium permanganate ($KMnO_4$). An equivalent volume of water is treated with the same volume of reagents, but the sulfuric acid (H_2SO_4) is added first to prevent oxidation. The difference between the titration of the blank and sample will give the amount of ferrous salt oxidized by the dissolved oxygen in the water; the dissolved oxygen content in parts per million may be calculated from this.

In the Winkler method the sample is collected in a glass-stoppered bottle, and solutions of manganous sulfate $MnSO_4$, and a mixture of sodium hydroxide, NaOH, and potassium iodide, KI, added. The manganous sulfate and sodium hydroxide form manganous hydroxide, $Mn(OH)_2$; part of this is oxidized to manganese oxy-hydroxide, $MnO(OH)_2$ by the dissolved oxygen present in the water. Then sulfuric acid is added; this dissolves the precipitate and liberates free iodine from the potassium iodide according to the following equation:

$$MnO(OH)_2+2H_2SO_4+2KI=MnSO_4+K_2SO_4+3H_2O+I_2$$

The amount of iodine liberated is proportioned to the amount of dissolved oxygen present; the free iodine is titrated with standard sodium thiosulfate, ($Na_2S_2O_3$), using starch paste as an indicator. Dissolved oxygen is reported in parts per million.

The Levy and Winkler methods have both been checked with the gasometric method on aerated distilled water. The Levy method has sometimes been condemned because it has seemed to give variable results[1]. On the other hand, it has been recommended because it is claimed that nitrites do not affect its accuracy.

1. Chlopin; Arch. f. Hygiene, 32, 294-309, 1898. Tiemann and Preusse; Ber., 12, pp. 1784-5.

The Winkler method checks with the gasometric method with uniformly good results[1]. This method gives high results if nitrites are present in the solution. Organic matter is said to reduce the iodine to some extent. "Standard Methods" reads, "If nitrites be present, correction must be made." This correction is not proportional to the amount of nitrite present since the reaction is catalytic. The first reaction is,

$$HNO_2+HI=H_2O+NO+I.$$

The nitric oxide then combines with oxygen from the air to form nitrous acid again, and this liberates more iodine. Winkler appreciated the fact that the second reaction does not take place until the iodine solution is exposed to the air, and oxidized the nitrous acid quantitatively in the bottle, by forming manganic chloride ($MnCl_3$) before the addition of potassium iodide. In a separate sample the amount of manganic chloride required for the destruction of the nitrous acid (HNO_2) was determined. The equivalent of this amount, in terms of dissolved oxygen, is deducted from the total dissolved oxygen.

Two modifications have been proposed for counteracting the effect of nitrites. The first was proposed by Rideal and Stewart[2]. This modification is based upon the principle that nitrites and organic matter may be oxidized by potassium permanganate in acid solution. A few drops of sulfuric acid are first added, then an excess of permanganate. After allowing the oxidation to proceed for 20 minutes, a strong solution of potassium oxalate ($K_2C_2O_4$) is added; this is followed by the usual Winkler procedure.

The second modification was proposed by Hale-Melia[3] This modification is evidently based upon the principle of the suppression of both nitrite reactions by the suppression of the hydrogen ion concentration. In this modification, after the sample has been acidified in carrying on the usual Winkler procedure, an excess of potassium acetate, $KC_2H_3O_2$, is added. This reacts with the sulfuric acid, as follows:

$$H_2SO_4+2KC_2H_3O_2=2HC_2H_3O_2+K_2SO_4$$

Acetic acid has a low hydrogen ion (H^+) concentration; Hale and Melia claim that the interaction of HNO_2 and KI does not take place under these conditions.

In considering Hale and Melia's modification, Elvove[4] has shown that iodine is destroyed by potassium acetate when

1. Winkler; Ber. 21, 2843-54, 1888. Kisch; Zeit. Angen. Chem., 1891, 105-8. Chlopin; Arch. f. Hyg., 27, 18-33, 1896. Spitta; Arch. f. Hyg., 38, 220, 1900. Birge and Juday; Wis. Sur. Bull., 22, 11-12.
2. Analyst, 26, 141-8.
3. Jour. Ind. and Eng. Chem., Dec. 1913, pp. 978.
4. Bull. 96, U.S. Hyg. Lab. pp. 26.

the sample stands for a long time before titration. If the potassium acetate is added from 15 to 30 minutes before the titration is carried out, the amount reduced is negligible.

As to organic matter, Hale and Melia claim that the iodine is not reduced to an appreciable extent by the organic matter present in mixtures of sewage and water.

The importance of comparing these methods has been realized by the Committee of the Laboratory Section of the American Public Health Association and a subcommittee was appointed in 1914 to undertake a comparative study to determine the accuracy, ease of manipulation and adaptability for laboratory and field work of the four methods. The chairman of the subcommittee, Professor E. B. Phelps, outlined the work for the committee.

In this paper the results and conclusions from my experimental work on these four methods are presented.

EXPERIMENTAL

Distilled water was aerated, and after 24 hours, its dissolved oxygen content was determined by both the Levy and Winkler methods.

Then .2 parts per million as nitrite was added in the form of sodium nitrite ($NaNO_2$) and the Levy Winkler, Hale Melia and Rideal-Stewart determinations made. Three samples were taken for each determination. Enough sodium nitrite was then added to bring the N as nitrite content up to .5 parts per million and the dissolved oxygen was again determined by the four methods. The averages of three determinations are reported in Table I. All except the Levy have been corrected for the volume of reagents introduced, as Winkler[1] claims that the concentrated solutions do not contain any dissolved oxygen. The standard permanganate for use with the Levy method and the standard thiosulfate for the other methods were checked against each other a number of times, and both solutions were found to be correct.

TABLE I.

	Aerated, distilled, H_2O	.2 p.p.m N as nitrite	.5 p.p.m. N as nitrite
Levy	8.23	8.17	8.17
Winkler	7.64	8.00	8.24
Rideal-Stewart		7.90	7.70
Hale-Melia		7.95	7.71

1. Zeit. Anal. Chem., 11, pp. 665.

The Levy values do not increase with nitrite but remain about the same as with distilled water—uniformly higher than the Winkler. The Winkler is .36 p.p.m. high with .2 p.p.m. N as nitrite, .60 p.p.m. high with .5 p.p.m. in N as nitrite Rideal-Stewart and Hale-Melia values are practically the same and check fairly well with the standard Winkler value on the same water, nitrite-free

The same procedure was followed with a second batch of samples with the exception that .5 and 1.0 p.p.m. N as nitrite were added. The results are shown in Table II.

TABLE II.

	Aerated, distilled, H_2O	.5 p.p.m. N as nitrite	1.0 p.p.m. N as nitrite
Levy	8.35	7.95	7.95
Winkler	7.58	7.97	8.79
Rideal-Stewart		7.48	7.56
Hale-Melia		7.84	7.61

Levy values are uniformly higher than the Winkler standard on distilled water. The Winkler is .39 p.p.m. high with .5 p.p.m. N as nitrite, 1.21 p.p.m. high with 1.0 p.p.m. N as nitrite. Rideal-Stewart and Hale-Melia values are approximately the same as the Winkler value on aerated distilled water.

In the next series of experiments 5 per cent and 10 per cent of sewage were added. The results are given in Table III. It must be remembered that the addition of fresh sewage to aerated distilled water reduces the dissolved oxygen content due to oxygen consumption by micro organisms, hence these results are comparable only in each dilution.

TABLE III.

	Aerated, distilled, H_2O	5 pct. sewage	10 pct. sewage
Levy	8.30	8.27	7.73
Winkler	7.95	7.42	6.78
Rideal-Stewart		7.32	6.81
Hale-Melia		7.25	6.65

In the presence of the organic matter of sewage, the Levy values are still considerably higher than the Winkler or its modifications. The Winkler, Rideal-Stewart and Hale-Melia values are all practically the same. Evidently the organic matter has not destroyed iodine to any extent.

This point was studied further, as follows:

Dissolved oxygen was determined in mixtures of nitrite-free sewage and aerated water; the remaining amount of liquid,

containing free iodine, was divided into two portions. One portion was kept exposed to the air in beakers, the other portion was kept in stoppered bottles out of contact with air. The results are given in Table IV.

TABLE IV.

Reduction of iodine by organic matter.

Percent Sewage	0	25	50	75	100
Dissolved Oxygen	8.08	5.16	2.41	.053	0.00
Dissolved Oxygen, in closed bottles after standing 1 week	8.00	4.40	1.54	3.30	0.00
Dissolved Oxygen in beakers	0.00 in 1 wk.	0.00 in 2 da.	0.00 in 1 da.	0.00 in ½ da.	

It would seem from this table that organic matter does not reduce iodine to an appreciable extent under the conditions of the Winkler method, in which the iodine solution is kept in closed bottles until ready for titration, and is exposed to the air but a few minutes during titration.

In the next series of experiments .5 p.p.m. N as nitrite and 5 per cent sewage was added. Then, keeping the nitrite constant, the sewage content was increased to 10 per cent. Results are given in Table V.

TABLE V.

	Aerated, distilled, H_2O	.5 p.p.m. N as nitrite 5 pct. sewage	10 pct. sewage
Levy	8.23	7.90	7.60
Winkler	7.55	7.54	6.99
Rideal-Stewart		7.07	6.54
Hale-Melia		7.14	6.47

Finally, 1.0 p.p.m. N as nitrite and 5 per cent sewage was added, then, keeping the nitrite constant, the sewage content was increased to 10 per cent. Results are given in Table VI.

TABLE VI.

	Aerated, distilled, H_2O	1.0 p.p.m. N as nitrite 5 pct. sewage	10 pct. sewage
Levy	8.95	8.50	7.72
Winkler	7.99	8.36	7.28
Rideal-Stewart		8.36	6.76
Hale-Melia		8.41	6.73

Levy values are invariably higher than any of the others; Winkler values are high in the presence of high nitrites; Rideal-Stewart and Hale-Melia agree very well.

The experiments shown in Tables I, II, III, V, and VI have been duplicated, with similar results, but the tables have not been included in this paper. In all, 300 dissolved oxygen determinations were made.

The general conclusions to be derived from this work are:

1. Levy values are higher than Winkler in practically all cases, except where high nitrites are present.

2. Winkler values are much too high in the presence of high nitrites. Either the Hale-Melia or the Rideal-Stewart modification will give correct results up to 1.0 p.p.m. N as nitrite and 10 per cent sewage. The procedure of the Hale-Melia is so much simpler than that of the Rideal-Stewart that it is much preferable for field work.

It is of interest to note that in a large number of comparative determinations of dissolved oxygen on the Illinois State Water Survey[1] were, on the average, 1.0 parts per million higher than results by the Winkler method used by the Sanitary District of Chicago.

The Levy method was used by the New York Metropolitan Sewerage Commission[2] in its work on New York Harbor. The Winkler method was used by Birge and Juday[3] in their extensive work on Wisconsin lakes. Phelps[4] has used the Rideal-Stewart method in his work on the Ohio River. Lederer[5] uses the Hale-Melia method at the Chicago Sanitary District; it is also used by Hale and Melia[6] at the Mt. Prospect Laboratory, Brooklyn, N. Y. Thus it is seen that a standard method is desirable in order that all results may be comparable. To this end the experiments indicate the advisability of discarding the Levy method, and of officially adopting the Winkler method, with the Hale-Melia modification in the presence of high nitrites.

The experimental work reported in this paper was done in the laboratories of the Illinois State Water Survey in July, 1914.

1. Unpublished work, Ill. St. Water Survey.
2. Report, N. Y. Met. Sewerage Comm., 1914.
3. Wisconsin Survey Bull. XXII, page 11.
4. Jour. Ind. and Eng. Chem., Aug. 1914, pp. 682.
5. Jour. Ind. and Eng. Chem., Nov. 1914, pp. 884.
6. Jour. Ind. and Eng. Chem., Dec. 1913, pp. 976.

Papers on Geology

Figure 1. A small anticline in a post-glacial valley. Huidekoper's Ravine, Meadville, Pennsylvania.

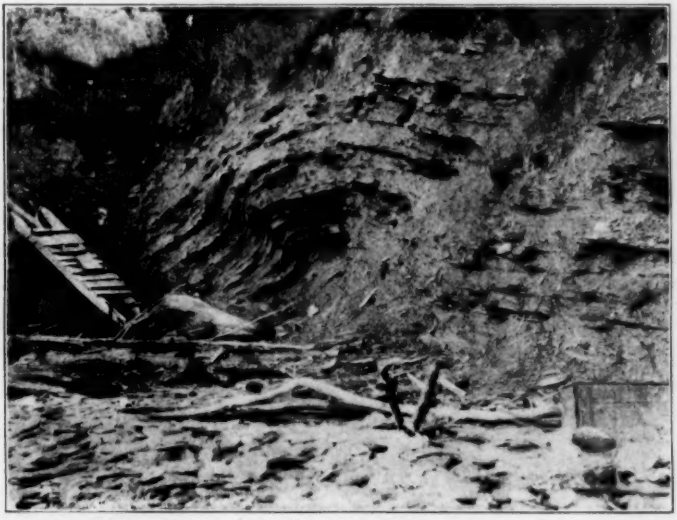

Figure 2. A fold in Portage Flaggs in lake cliff. Three miles east of Erie, Pennsylvania.

RECENT CRUSTAL MOVEMENTS IN THE EASTERN PART OF THE GREAT LAKES REGION

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INTRODUCTION

While in the region of the Great Lakes and along the Atlantic Coast, careful search has been made for even slight vertical movements in recent geological time, little attention has been given to recent tangential movements in either of these areas. The present study has been initiated in the eastern part of the Great Lakes Region to determine the age, distribution, extent, and significance of these tangential movements.

The rocks of northeastern Ohio and northwestern Pennsylvania and New York for the most part appear horizontal. However, a study of their distribution shows a gentle dip toward the southwest[1]. Exceptions to this gentle dip in the way of folds were noted early, and recent study is increasing the number of these exceptions very materially, especially between Cleveland, Ohio, and Westfield, New York.

PREVIOUS STUDY

Hall described and figured some folds in 1843 in northwestern New York[2], and in 1910 Van Horn described some small anticlines in the Chagrin shales near Cleveland, Ohio[3], but neither considered the edge of the folds. Gilbert[4] in 1886 recognized that some folds in northwestern New York were post-glacial, and presented a paper on "Some New Geologic Wrinkles." In 1903 Smallwood and Hopkins[5] described some small anticlines near Meadville, Pennsylvania. While these writers did not specially consider the age of the deformation, recency is implied by the origin assigned for the folds, landslides on the valley walls. However, most of these folds are in no way related to the landslides, and the few that are seem to have no causal relation with them, so an inference of recency because of such relation has little or no force.

AGE OF THE ROCKS

The rocks affected by the disturbances in the area under consideration range in age from Middle Devonian to Lower Mississippian[6].

1. I. C. White: Second Geol. Surv. of Pa., Report Q4, 1881, pp. 44-49.
2. Geol. of Fourth Dist., N. Y., pp. 295-298.
3. Bull. Geo. Soc. America, vol. 21, pp. 771-773.
4. Proc. Amer. Assoc. Adv. Sci., vol. 35, p. 227.
5. Bull. Syracuse Univ., Series IV. No. 1, pp. 18-24.
6. I. C. White, Second Geol. Surv. Pa., Report Q4. pp. 93-119.

CHARACTERISTICS OF THE ROCKS

Shales are the dominant rocks among those exposed in this area. Except for a few sandstones, they are nearly all shales with thin sandstone beds interspersed. The sandstone beds in the shales increase both in number and in thickness in the older formations, so that in the oldest formation, the Portage, flaggy sandstones constitute an important part of the rock, and some of the beds are a foot or more in thickness.

NATURE AND EXTENT OF DEFORMATION

The deformation includes folds and faults. Of the folds there are two types—those with longer axes parallel to the valleys and those with their axes transverse to valleys. These two types are found not together but in different areas. The faults, so far studied, are all thrusts, with possibly one slight exception.

FOLDS PARALLEL TO VALLEYS

The first type of folds noted above consists of small anticlines in the bottoms of valleys that trench the uplands (Fig. 1). These folds involve only a few feet of strata, and rarely affect the walls of the post-glacial valleys in which they are most commonly found. Some of these anticlines are narrow and close, while others are broad and open. They are variable also in length, ranging from a few feet in some instances to over 100 feet in others. While the axes of the folds vary somewhat in direction, most of them trend nearly with the valleys in which they occur. Though the folds seem to have been formed as the valleys developed, no definite evidence of age has been noted in connection with them, and they are small and unimportant when compared with many of the folds of the second type.

FOLDS TRANSVERSE TO VALLEYS

In the second type of folds the axes are chiefly transverse to the valleys, and they affect not only flood-plains, terraces, and walls of valleys, but they occur also in the lake cliffs east of Erie, Pennsylvania. (Fig. 2). Some anticlines occur alone, but frequently several are associated with synclines in a series. These folds commonly involve from 10 to 20 feet, and in some instances 60 to 80 feet, of strata exposed above the stream bed and an unknown amount below it. The folds vary in width from a few feet to over 500 feet. Many folds may be seen distinctly on both sides of a stream.

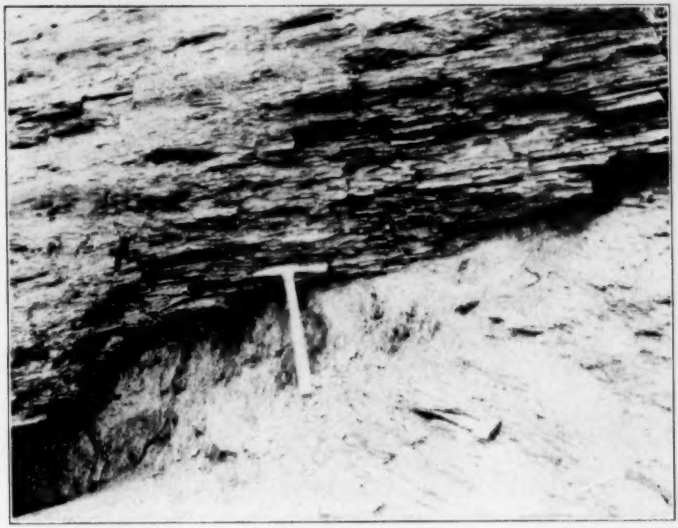

Figure 3. A fault showing brecciated zone with upturned beds still attached to downthrown side. A mile south of Girard, Pennsylvania.

Figure 4. An asymmetrical fold deforming the surface of a forty-foot terrace. A fault below grades into this fold above. Little Elk Creek, five miles south of Girard, Pennsylvania.

THRUST FAULTS

Many of the transverse folds are accompanied by thrust faults. Some faults occur in the middle of an anticline and others at the edge next a syncline. Some faults grade into folds above, others feather out in the loose upper shales, while still others break clear across the strata. Though the displacement of beds is generally less than ten feet, and may be less than a foot, many of the fault planes are marked by distinct brecciated zones. The evidence of overthrust in one of these faults seems very decisive, for the upturned edges of the soft shales are still attached to the ends of the downthrown beds, while the downturned ends on the upthrow side have been broken off and ground fine by the movement of the upthrown rocks over them (Fig 3).

AGE OF FOLDS AND FAULTS

The rocks themselves fix the age of the folds and faults only as later than Devonian or Mississippian, but the relations of these movements to glaciated surfaces, glacial deposits, terraces, and flood-plains, show that many of them are not only post-glacial, but that they are later than the low stream terraces, and that a few of them are even later than the present flood-plains.

The evidence of recency is seen in the rise of the loose top of a fold distinctly above glaciated surfaces on either side (Fig. 2), and in the deformation of glacial deposits above the fold in such a manner that surface drainage has been affected and a recent gully started along the fold parallel to the axis.

Other evidences of recency are found in the deformation of the surface of a terrace by a fold or fault, and in the uneroded condition of the top of fold or fault in a terrace (Fig. 4).

In like manner, the deformation of the surface of a flood-plain by a fold or fault, or the uneroded top of fold or fault in the flood-plain, shows that it is more recent than the flood-plain.

Though not so definite as to time, other evidences of recency are seen in the freshness of the brecciated fault zones and in the unweathered condition of joints near the surface.

CONCLUSIONS

A reconnaisance was made by the writer of parts of the larger streams flowing into Lake Erie from Sandusky, Ohio,

eastward to Westfield, New York. While distinct folds of considerable size were found particularly along the Vermilion and Black rivers in northern Ohio, no evidence of recency was found in connection with any of the folds until in the vicinity of Cleveland. From there eastward through northeastern Ohio and northwestern Pennsylvania and New York the rocks have suffered recent deformation in a manner not duplicated in those in adjacent glaciated areas.

Though these movements have not been studied eastward, there is evidence that they extend much farther in that direction, and some of them have been noted on the north side of the lakes as well.

THE LOESS IN ILLINOIS: ITS ORIGIN AND AGE

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INTRODUCTION

In spite of the fear that it might appear presumptive to present a paper on the much discussed problem of the loess before this Academy, it seemed to the writer that there is need at this time of a more extended statement than can be made in the ordinary geologic reports of the main facts of the loess deposits and of the interpretation which those facts reasonably support.

The name loess is applied to the fine-grained silt-like deposit that, over portions of Illinois and elsewhere in the Upper Mississippi Valley, lies at and immediately beneath the surface to a variable depth of from 2 or 3 to 50 or more feet. On the hills it is generally yellow, but over the more level, poorly drained areas the soil developed at the top of the loess is colored dark with organic matter to a depth of 1 to 3 feet, below which the color grades through shades of gray to yellowish brown. The deposits rarely show any trace of stratification or lamination, and where cut by streams or excavations it tends to stand for a long time in nearly vertical cliffs. In the dryer places, especially in the thicker deposits on the hills, the loess contains numerous shells of species of air breathing gastropods that now inhabit forest-covered slopes. In its typical development the loess is practically limited to the Mississippi basin and in this region it sustains peculiar relations to certain topographic features and to certain beds of glacial drift.

Figure 8. Moraine-like hills of loess bordering the Iowan drift margin in Tama county, Iowa.

DISTRIBUTION OF THE LOESS

The loess covered area in the Mississippi Valley is chiefly confined to the surface of the older (Kansan and Illinoian) drift sheets and the driftless area, and is mostly included between the Missouri and the Wabash rivers, occurring in its typical characters but a few miles west of the Missouri, and extending east of the Wabash in the vicinity of the Ohio river for several miles east of Cincinnati. South of the Ohio river the loess is chiefly limited to a rather narrow belt adjacent to the Mississippi, nearly to its mouth.

Within this general area the distribution of the loess presents the following significant peculiarities:

1. Except where local topographic features have modified the normal deposition, it is thickest, most typical and most generally fossiliferous on the bluffs bordering the east side of the larger stream valleys, as along the Missouri, Mississippi Illinois, Wabash and smaller rivers, the thickness generally decreasing with increasing distance from the streams. This peculiarity has been noted by all of the students of the loess.

Leverett[1] says that the general thickness of the loess on the east side of the Mississippi Valley from the driftless area southward the entire length of Illinois, is much greater than on the west side in Iowa and Missouri; probably twice as great; and a similar difference exists on the east and west sides of the Valley of the Wabash river.

Shimek[2] says that the bluffs of the Missouri river from Sioux City to Kansas City, and those bordering the Mississippi are higher, with thicker loess deposits on the east side than on the west.

In his report on the St. Louis Quadrangle, Fenneman[3] says that the loess is thickest on the east bluffs of the Mississippi and Missouri rivers where in some places it reaches 50 feet, but it thins to only 10 or 15 feet at a distance of only a few miles.

In many places along the rivers of Illinois as opposite Burlington and below Alton along the Mississippi, the loess has accumulated on the east bluff in dune-like ridges that stand 25 to 50 feet above the uplands farther east, and appear as billowy ridges fringing the east banks of the streams.

1. Frank Leverett: The Illinois Glacial Lobe. Mon. XXXVIII U. S. Geol. Survey, 1899, p. 183.
2. B. Shimek: Loess Papers. Bul. from the Laboratories of Nat. Hist. of the State of Iowa, Vol. V, No. 4, p. 371. Nov. 1904.
3. N. M. Fenneman: Geo. and Mineral Resources of the St. Louis Quadrangle. Bul. No. 438, U. S. Geol. Survey, 1911, p. 33.

2. A belt of moraine-like hills, composed of loess instead of till, borders the Iowan drift sheet in Iowa, as shown in figure 1, and continues as an unusually thick deposit, but with decreasing thickness for a considerable distance south and east of the margin of this drift sheet.

3. The loess is very thin and patchy or entirely absent, over the surface of the younger (Iowan and Wisconsin) drift sheets in all of this region.

4. Over the upland areas of the older (Kansan and Illinoian) drift sheets the loess has its greatest development in Iowa and northern Illinois, where its average thickness is 10 to 15 or more feet. The thickness diminishes notably towards the south and east, being only 1 to 4 feet over the interstream areas in southern Illinois south of the Kaskaskia river, and south of the Wisconsin drift sheet in Illinois, Indiana, and Ohio. In this region of thin loess the deposit is not so homogeneous as it is farther north; in many places the upper 12 to 18 inches being very porous, and of a white, ashy appearance, and often being referred to as "White Clay." Below this white superficial portion the material is brown and much more clayey and compact, and tends to break into small prismatic blocks when dry. This peculiarity is thought to have been developed by the finest particles of the surface loess having been carried downward by ground water, leaving the upper part very porous, but forming a compact deposit where these finer particles became lodged in the small cracks and interstices lower down. The general distribution of the loess in Illinois is shown on the accompanying map. (Plate 1).

COMPOSITION OF THE LOESS

The loess is composed of very small angular undecomposed mineral particles, of which quartz predominates and feldspar, hornblend, calcite, dolomite and other minerals are also common. The texture is usually quite uniform except for occasional pebbles ranging in size to one inch in diameter, which occur in the lower 2 to 5 feet of the deposit. It is thought that these pebbles were not originally deposited with the loess as will be shown later. Some of them are of chert or limestone or sandstone of local origin and others are of crystaline rock. Any kind of pebbles common in the underlying till may occasionally occur in the lower part of the overlying loess, not only on the hills and slopes, but also over the more level areas.

The following table of mechanical analyses of loess from a number of localities shows the texture of the upper part of this deposit in different parts of the state.

Plate I. Map showing by oblique lines the area of main loess distribution in Illinois.

*MECHANICAL ANALYSIS OF THE LOESS IN ILLINOIS

Diam. in Millimeters	Conventional Name	E. Dubuque 1-15 in.	Rock Island 1-4 in.	Carrollton 1-15	Virginia City 4-48	Near Greenup 2-15 in.	Newaqua 2-18 in.	Galatea 1-18	Champaign Bowlder Clay 30-42 in.
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
2-1	Fine gravel	0.00	0.00	0.00	0.00	0.30	0.00	0.00	1.04
1-.5	Coarse sand	0.00	0.00	0.00	0.00	1.05	0.08	0.00	1.98
.5-.25	Medium sand	0.04	0.02	0.01	0.00	3.42	0.77	0.02	6.85
.25-.1	Fine sand	0.74	0.17	0.04	0.01	3.30	0.11	0.30	6.23
.1-.05	Very fine sand	30.12	22.27	9.93	7.68	6.47	4.88	5.21	5.82
.05-.01	Silt	41.49	51.53	48.76	61.85	55.48	52.50	57.75	28.38
.01-.005	Fine silt	7.96	9.72	8.39	9.60	11.70	12.15	12.78	15.46
.005-.0001	Clay	14.44	12.08	23.65	15.15	14.90	22.10	20.36	30.00
Total Mineral Matter		94.79	95.79	93.78	94.29	96.62	92.59	96.42	95.64
Organic Matter Water Loss		5.21	4.21	6.22	5.71	3.38	6.61	3.58	4.36
Loss by Direct Ignition		5.66	4.21	6.14	5.87	3.11	5.73	6.01	

* Whitney, Milton: Report on the examination of some soils from Illinois; report of the Illinois Board of World's Fair Commissioners, 1893, pp. 103-106.

From this table it may be seen that the greater part of the loess is composed of particles intermediate in size between sand and clay, but that it grades into sand on the one hand and into clay on the other. The table also shows that the loess in the vicinity of the larger streams, and in western Illinois, contains a larger percentage of coarser particles than that over the uplands some distance from the streams, and in the eastern part of the state. Compared with the drift or bowlder clay, shown in the right hand column, the loess contains a smaller percentage of either the coarse or very fine constituents and a relatively larger percentage of particles of intermediate size.

SOURCE OF THE LOESS MATERIALS

Two sources have been suggested for the materials of the loess. Some geologists have assumed that it has been blown by the winds from the arid regions of the Great Plains, while others think it has been derived from the rock flour of glacial till. The former theory is discredited by the following facts:

1. The small size of the particles of the surface soil of the arid regions. Merrill[4] says "the particles of adobe or surface soil of the Great plains vary in size from those too small for measurement, up to .08 millimeters in diameter. It will be seen from the former table that both the maximum and minimum size of the particles of the loess are larger than those of adobe, which is the opposite of what would be expected if the latter was the source of the loess.

2. The constituents of adobe contain a much larger proportion of calcium carbonate and of mineral matter derived from sedimentary rocks than does the loess.

3. The peculiar distribution of the loess in relation to the drift deposits of the upper Mississippi Valley. Chamberlin says, "The constitution of the loess of the Mississippi Valley taken with its two distributive relationships proves it to have a special origin from the glacial drift."

4. Adobe soil is much more variable in its chemical composition than the loess, as appears in the following comparative table of analyses in which columns 1 to 5 show the analyses of loess from different localities, and columns 6 and 7 are those of adobe soil.

The peculiar relations of the loess to the various drift sheets and to the streams of the glaciated region and the rseemblance of the loess in freshness and mineral composition to the finer parts of the till, furnish convincing evidence that the source of the loess material was glacial drift. It also seems reasonable to assume that the belts of greatest thickness of the loess are nearest the immediate sources of supply. If this is true the main immediate sources of the loess are, 1, river flood plains, and 2, the Iowan drift sheet.

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4. George P. Merrill: Rocks, Rock Weathering and Soils; p. 321, 1916.

*TABLE OF ANALYSIS OF LOESS AND ADOBE SOIL

	No. 1 Dubuque	No. 2 Galena	No. 3 Kansas City	No. 4 Vicksburg	No. 5 Near Terra Haute	No. 6 Adobe Santa Fe N- Mex	No. 7 Adobe Salt Lake City, Utah
SiO_2	72.68	64.61	74.46	60.69	79.77	66.69	19.24
Al_2O_3	12.03	10.64	12.26	7.95	9.95	14.16	3.26
Fe_2O_3	3.53	2.61	3.25	2.61	3.39	4.38	1.09
FeO	.96	.51	.12	.67			
TiO_2	.72	.40	.14	.52	.70		
P_2O_5	.23	.06	.09	.13		.29	.23
NnO	.06	.05	.02	.12		.09	Trace
CaO	1.59	5.41	1.69	8.96	.67	2.49	38.94
MgO	1.11	3.69	1.12	4.36	.26	1.28	2.75
Na_2O	1.68	1.35	1.43	1.17	1.08	.57	Trace
K_2O	2.13	2.06	1.83	1.08	2.05	1.21	Trace
H_2O*	2.50	2.05	2.70	1.14	2.55	4.94	1.67
CO_2	.39	6.31	.49	9.63		.77	29.57
SO_3	.51	.11	.06	.12		.41	.53
C (Organic)	.09	.13	.12	.19		2.00	2.96

*Contains H of organic matter in Nos. 1-4.

1. Nos. 1 to 5: Leverett, Frank: The Illinois Glacial Lobe. Mon. XXXVIII, U. S. Geo.. Survey, 1899, p. 164.

Nos. 6 and 7: Clark, F. W.; The Data of Geochemistry. Bul. No. 491, U. S. Geol. Survey, p. 487.

MODE OF ACCUMULATION OF THE LOESS

Orton suggested that the loess or white clay of southwest Ohio represented the fine materials brought up by earth worms and other burrowing animals from the underlying till. That the aggregate work of earth worms is considerable, no one will doubt, but the inadequacy of such agents in the accumulation of the loess will be readily seen in the places where the deposits have a thickness of several feet. It is also shown in the fact that in the same general region there is no perceptible difference in the thickness of the loess whether it is immediately underlain by drift or by such beds as gravel, sand, soil or peat, which contain no fine constituents resembling loess. The clear zone of contact that in most places separates the loess from the underlying bed shows that the disturbance produced by earthworms and other burrowing animals are relatively unimportant as far as loess accumulation is concerned. The indifference in the thickness of the loess to the character of the bed that lies beneath it, as stated above, indicates that the loess could not have been derived from the underlying deposit, but that it was transported, and laid down above the material upon which it rests. The homogeneous, well sorted character of the loess is proof that it has been carried and deposited either by wind or water, for no other geological agent is capable of so thoroughly sorting the material it deposits.

The general distribution of the loess, being thicker and coarser on the hills bordering the larger streams than over interstream areas (see figure 2), and especially thick on the tops of the hills, bordering the windward side of the valleys and around the border of the Iowan drift plain, in Iowa, and towards the north in Iowa and northern Illinois than farther south; the great range of relief shown in the loess deposits, being more than 600 feet in Illinois, and exceeding a thousand feet in the Mississippi basin; the fact that the loess does not tend to level the inequalities of the surface, but mantles the hills, prairies and lowlands; the general lack of stratification or lamination of the deposits; and the presence in the loess of entire shells (many of which are fragile and easily broken) of species of terrestrial gastropods that now live on dry woodland hills, are conclusive evidences that the loess in the Mississippi Valley region was carried and deposited by wind, rather than by water.

Water laid silts are distinguishable from true loess by the greater distinctness and horizontality of their stratification, by the more heterogeneous character of their constituent materials and by the fact that their fossils, when present, are aquatic. If sediments possessing these characters of aqueous deposition were never included under loess deposits, it would tend to clear up and prevent much of the confusion that is now so prevalent concerning the loess. There is no more reason for designating water laid deposits resembling loess in texture, or even derived from loess by the name loess, than there is for applying the name shale to fluviated deposits derived from beds of shale. In geologic mapping all such water laid deposits would be classed as alluvium.

Calvin[8] has pointed out that there are three things to account for in the proper explanation of loess deposition:

1. An extensive gathering ground of bare and dry surfaces as a direct source of the material.

2. An agent of transportation and deposition consistent with the source of supply and the sites of deposition.

3. Obstructions to the transporting agent, such as would result in deposition and lodgment in the places where such deposits now occur.

All the above conditions are completely satisfied in harmony with deposition of the loess by winds. The position of the thicker and coarser loess deposits on the bluffs bordering the windward side of the larger flood plains are in the places where the prevailing westerly winds, after sweeping over exposed

8. Samuel Calvin: The Iowan Drift. Journal of Geology, Vol. XIX, No. 7, 1911, p. 601.

flood plain areas, would have their velocity checked and so be compelled to drop a part of their load on the bordering banks, which then as now, were doubtless forest covered and so furnished lodgment for a part of the silts deposited upon them. A large part of the material would always be carried beyond the bordering hills and finally be dropped upon the interstream areas.

Even the details of thick loess distribution bordering the streams are in harmony with wind deposition, for the thickest loess is not where the winds blow straight across the valleys, but is on the bluffs bordering those portions of the valleys which trend oblique to the prevailing wind currents, so that the winds followed along the valley for some distance before their movements were obstructed by a bend in the channel. This is illustrated by the deposits along the Sangamon river in the Springfield Quadrangle. The deposits of the thick loess around the margin of the Iowan drift sheet and extending with decreasing thickness for many miles to the south and east are also consistently explained only by the agency of the wind The most striking characteristics of the Iowan drift sheet are, 1, the thinness of the drift; 2, the lack of the usual amount of fine material and the presence of great numbers of bowlders upon its surface, and, 3, the moraine like hills of loess bordering the area. All of these peculiarities would be developed as a result of winds blowing outward over the surface of the glacier, or over the dried mud flats of the drift sheet, after the glacier had retreated to the northward, but before a cover of vegetation had become established upon the drift surface. Winds sweeping unchecked over the bare drift surface during dry periods would pick up large quantities of the finer materials. A part of their load would be dropped when the forest that fringed the border of the Iowan drift area was encountered and a part would be carried farther forward. If such conditions attended the withdrawal of the Iowan ice sheet as resulted in the surface of the drift remaining bare of vegetation for a long time, the bowlders and coarser debris of the till would become concentrated at the surface by the removal by the winds of a large part of the finer constituents, reducing by this great amount the thickness of the Iowan drift.

A part of the material gathered by the winds from the river flood plains or from the Iowan drift surface would be dropped at the immediate border, a part would be carried for a longer or shorter distance before finding permanent lodgment in the vegetation that covered the uplands. Another part dropped in places not well protected with vegetation, was doubtless again

picked up, together with fine material from other sources and carried forward for some distance and again dropped, and the process was repeated again and again until the fine silt was spread widely over the interstream areas, and much of it is now a long distance from its original source.

SOURCE OF THE PEBBLES IN THE LOESS

Pebbles are rare in the loess, but a few occur in the lower 2 to 5 feet of the deposit over practically all of the loess area, being more frequent where the loess is thin than where it is best developed. The presence of occasional pebbles in the lower part of the loess has been considered by some geologists as evidence of the aqueous origin of at least this portion of the deposit, but it is just as difficult to explain how occasional pebbles could be included in the midst of an otherwise homogeneous, fine grained, unstratified deposit laid down by water as in such a deposit made by wind.

A study of the process of accumulation of the loess now forming over the surface of the early Wisconsin till has furnished valuable information concerning the probable source and manner of inclusion of the pebbles in the lower part of the loess in other regions. The higher portions of the surface of the early Wisconsin till in Champaign county are in places covered with 1 to 3 feet of porous, fine grained, loess-like material which, like the loess in other places in the State, is largely composed of minute, fresh, angular fragments of quartz, feldspar, hornblende, and other minerals derived from igneous rocks. In this recent loess small pebbles are somewhat more numerous than in the lower part of thicker loess deposits over the Illinoian and Kansan drift sheets, probably on account of the slower rate of accumulation of the loess now forming on the Wisconsin drift, compared with the rate at which the loess accumulated in early Peorian time.

Over the more dry, uncultivated areas of this surface burrows of ground squirrels and other animals are common. Many of these burrows pass through the thin loess mantle into the unlerlying till, and the dirt thrown out around the tops of the holes often contains a few small pebbles. In poorly drained areas crayfish holes are in places almost as numerous as the burrows on the higher lands. In the craters built up around the tops of these holes a few pebbles ranging in size up to one inch in diameter were collected. Pebbles are also occasionally carried from areas where no loess is present to areas where loess is accumulating in the mud on the feet of hoofed animals.

In all of these ways occasional pebbles are now being scattered on the surface of, and becoming imbedded in, the loess accumulating upon the Wisconsin till, but each of these agencies gradually becomes less effective and will eventually fail to scatter any pebbles, as the thickness of the loess increases. It is believed that by means similar to the above the pebbles became incorporated in the lower part of the loess deposit as it was in process of accumulation over the main loess covered regions.

RELIEF OF THE PRE-LOESSIAL SURFACE

The relief of the surface of the Illinoian drift sheet at the time the loess was laid down upon it was worked out in detail in the Avon and Canton quadrangles in the northcentral part of the State where the loess is well developed. This was determined by finding the elevation of the upper surface of the drift, and thus of the lower surface of the loess at a large number of places where the contact was exposed as shown on the map, (plate 2). The relief of the surface of the drift beneath the loess in the Canton quadrangle was found to exceed 150 feet, and the general slope of the top of the drift beneath the loess in this region was found to correspond in a general way to the slope of the present surface. The main divides of the region at the time the loess was deposited were the same as at present. In the Canton quadrangle the main highland which then, as now, lay between Farmington and Norris, extended a little south of west past the town of Fairview. From this highland the pre-loessial surface declined southward along Copperas Creek as much as 100 feet in a distance of 6 miles. Along Big Creek, from its sources in the vicinity of Norris to the town of St. David, the total difference in the elevation of the drift surface beneath the loess exceeds 125 feet. From the headwaters of Put Creek to the place where it leaves the quadrangle near the southwest corner, the surface declines more than 100 feet. A like difference in the altitude of the upper surface of the drift is shown between the head waters of Turkey Creek and Coal Creek and the top of the drift bordering these streams at the west side of the quadrangle. From the sources of Littlers Creek to its junction with Spaan River the pre-loessial drift surface declined 150 feet.

The topography of the Illinoian drift surface beneath the loess in the Avon quadrangle resembles that of the Canton quadrangle described above, as does also the pre-loessial surface of the drift in the Sumner and Hardinville quadrangles in Southeastern Illinois, and the Herrin quadrangle in the southern part of the state.

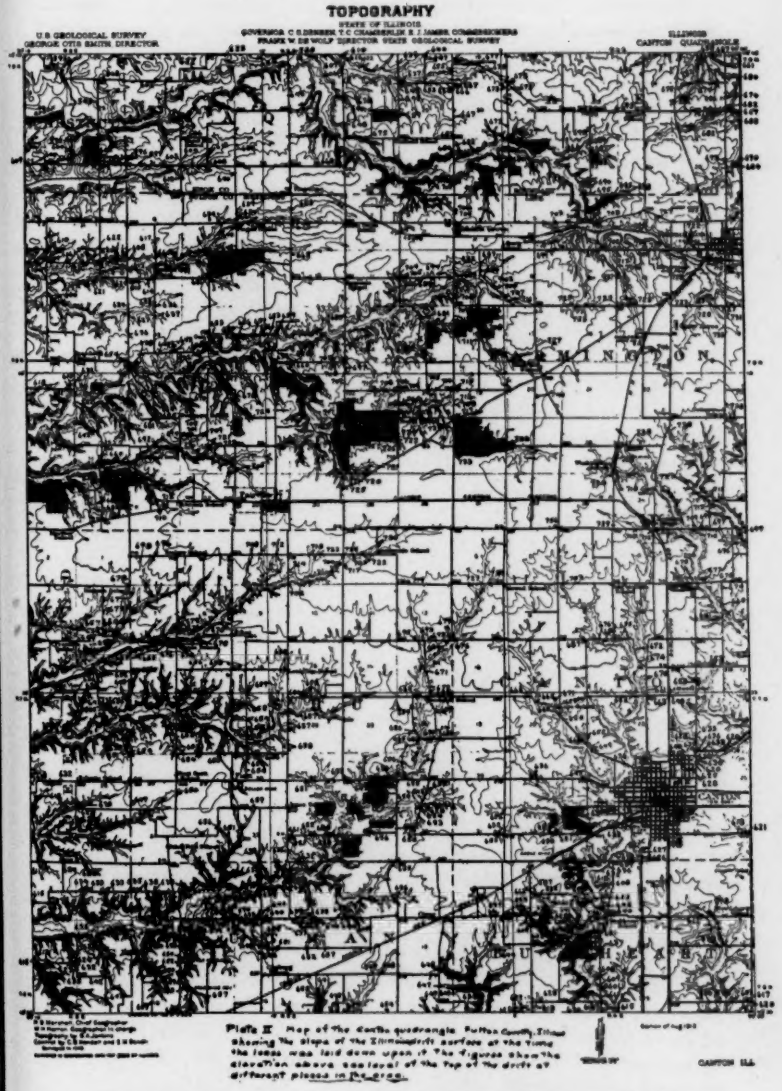
TOPOGRAPHY
U S GEOLOGICAL SURVEY
GEORGE OTIS SMITH DIRECTOR
STATE OF ILLINOIS
GOVERNOR C S DENEEN T C CHAMBERLIN E J JAMES COMMISSIONERS
FRANK W DE WOLF DIRECTOR STATE GEOLOGICAL SURVEY
ILLINOIS
CANTON QUADRANGLE
M I N O N
Plate II Map of the Canton quadrangle Fulton County Illinois showing the slopes of the Illinoian drift surface at the time the loess was laid down upon it The figures show the elevation above sea level of the top of the drift at different places in the area
CANTON ILL.

Plate II. Map of the Canton quadrangle, Fulton county, Illinois, showing the slopes of the Illinoian drift surface at the time the loess was laid down upon it. The figures show the elevation above sea level at the top of the drift at different places in the area.

From the detailed study of these and other areas it seems certain that the development of erosion slopes on the surface of the Illinoian drift previous to the deposition of the loess was several times that at present attained on the surface of the Early Wisconsin drift, indicating a correspondingly longer interval for its accomplishment than has elapsed since the withdrawal of the Wisconsin ice sheet.

It might be suggested that the surface of the Illinoian till, beneath the loess, reproduced the topography of the pre-Illinoian surface as a result of the present streams following pre-Illinoian channels that were not completely filled by the Illinoian till. Some of the larger streams in the Canton quadrangle are following pre-Illinoian channels, but only in a part of their courses, and many of the smaller streams have no place found buried channels. However, the slopes of the Illinoian till, beneath the loess, bordering the portions of the stream valleys, where they do not follow pre-Illinoian channels, are just as gradual as in the places where they do. The thickness of the Illinoian till in this region averages about 24 feet, which depth is sufficient to entirely obliterate all of the smaller pre-Illinoian valleys and many of the larger ones also, as the field study shows it has done. Hence the generally gradual slopes of the surface of the till, beneath the loess, bordering the smaller as well as the larger streams, could have been developed for the most part only by stream erosion on the surface of the Illinoian till, before the overlying loess was laid down.

TIME OF THE MAIN LOESS DEPOSITION

In the Mississippi Valley and elsewhere dust is at present being carried and deposited by the winds, and doubtless under favorable conditions of gathering and lodgment, the winds have carried and deposited such materials throughout past geological periods. It seems certain, however, that peculiar conditions unusually favorable for loess deposition, prevailed over the Mississippi valley during very late Iowan and early Peorian stages of the Pleistocene. This is shown, (1) by the intimate relations of the loess to the border of the Iowan drift plain above described, and (2) by the very slight development of loess on the surface by the Iowan and Wisconsin drift sheets compared with its much greater thickness over the older Kansan and Illinoian till.

That the most important loess deposition did not take place after the Iowan period of glaciation is shown by the absence of anything like such thickness of loess over the Iowan

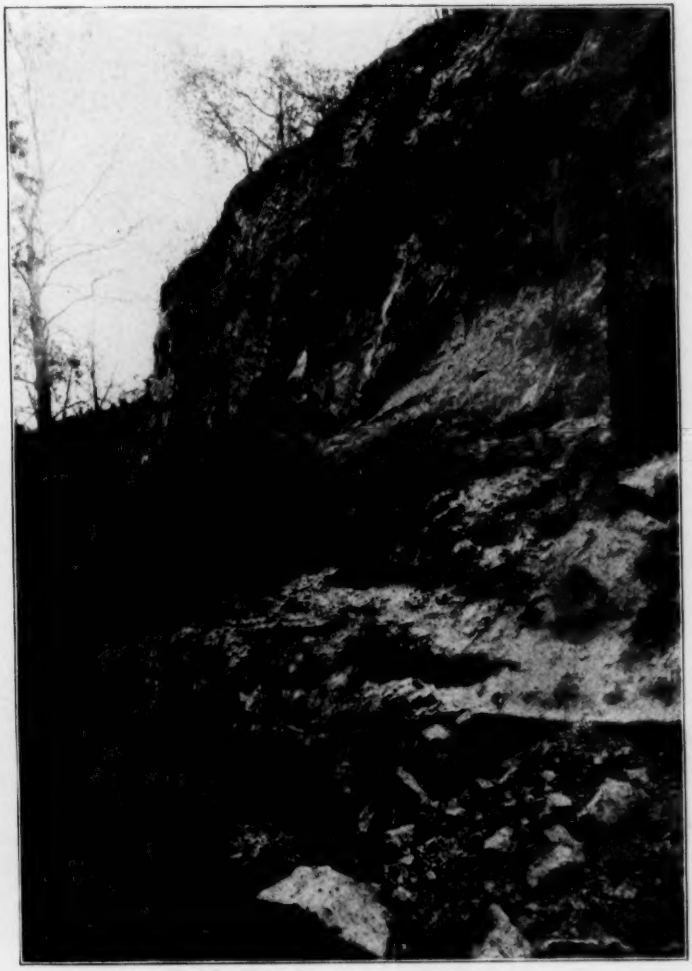

Figure 9. Bluff of loess along the Mississippi River in Calhoun county, Illinois.

and Wisconsin drift sheets as is present over the surface of the older Illinoian and Kansan till. The maximum loess deposition did not occur until a long time after the Illinoian till was deposited as shown by the fact that (1) before the loess was deposited sufficient time elapsed for the development, on the surface of the Illinoian till, of erosion slopes and relief quite similar to those of the present surface; and (2) the interval between the deposition of the Illinoian till and of the overlying loess in Illinois was sufficiently long for the development in many places upon the surface of the Illinoian drift of the Sangamon soil horizon and beds of peat, and in others of an oxidized and weathered zone, and in still others of a zone of concentrated pebbles on the slopes by the removal of the finer constituents of the till, such as are found above the Illinoian till and below the loess in many places in Sangamon, Fulton, Menard, Champaign and other counties in Illinois.

Some loess-like material was doubtless deposited by the winds during each of the interglacial stages, for thin deposits of such character are known between the Kansan and the Illinoian and the Kansan and the Iowan drift sheets at numbers of places in the Mississippi Valley. However, the thickness of the loess between the Kansan and Illinoian till or between the Kansan and the Iowan is not nearly so great as that over the surface of the Kansan and the Illinoian till sheets. The pre-Iowan loess appears to have been limited in its distribution, compared with the present loess deposits, as is indicated by the following facts: (1) The loess is thin, only one to three feet, and of relatively rare occurrence between the Illinoian and the Kansan or between the Kansan and the Iowan drift sheets, while a thickness of several feet is common between the Illinoian and the Wisconsin till. (2) Masses of typical fossiliferous loess, in size up to 15 feet long and 4 feet thick, are often found incorporated in the Wisconsin till, but they are rarely or never found in the till of earlier age, in which masses of sand of corresponding size are not uncommon.

The relations of the loess to the drift varies with the valley slopes. In many places where the banks bordering the valleys of the larger streams are steep, the loess breaks off abruptly near the top at the uppermost exposed level of the till. In many other places where the bordering slopes are gentle and are favorably situated with respect to areas of flood plain and the direction of prevailing winds, a mantle of normal loess covers the slope to a thickness of from two or three to six or eight feet, often extending down almost or entirely to the level of the flood plain.

In the places where the loess terminates abruptly near the tops of the hills, at the uppermost level of the till, the banks are usually precipitous, and the streams have undercut their banks and thus widened their valleys since the time of major deposition of the loess. In this process the loess that was deposited in the earlier slopes has been removed as the work of valley widening by side cutting of the streams was accomplished. At these places the undercutting has taken place so recently that the banks are still steep and no appreciable amount of loess in excess of what has been eroded, has since been deposited upon them.

In some places where the loess continues down the slopes for a considerable distance below the upper level of the drift, the slopes are usually gentle, showing that undercutting has not there been in progress for a long time.

The presence of the loess over the slopes below the upper level of the drift may be accounted for in two possible ways: (1) It may be assumed to have been brought down from higher levels by slumping and sheet wash; and (2) It may have been carried up by winds from flood plain or other exposed areas and deposited on the slopes where it is now found. By the first assumption practically all the loess on such slopes would be of secondary origin, while by the second this loess would be largely in its original position.

The first assumption is open to the following objections:

1. Although landslides and slumping were doubtless important factors in the development of the gentle slopes, after undercutting had ceased, yet these processes would not result in the development over the surface of a mantle of fine homogeneous loess material, unmixed with till, after the gentle slope had been developed. 2. The effective action of sheet wash on slopes of rather uniform gradient tends to increase with the distance down slope from the top, so that any material transported for a distance near the top would tend to be carried to the foot and not deposited on the middle or lower part of the slope. 3. The thickness of the loess at the top of the hill, in places where the loess continues down the slope to the flood plain, is as great as it is in the places where it does not extend below the highest level of the drift. An immense quantity of material would be required to cover a slope ⅛ to ¼ mile in length to a depth of three to six feet, yet in not one of such places observed was there any diminution in the thickness or amount of the loess at the tops of the hills, showing conclusively that the loess on the slopes could not have been derived from the loess at the top of the hill.

Supporting the view that the loess which mantles the slopes below the highest level of the drift is an original deposit, is the general relation of such loess covered slopes to areas of flood plain and to the direction of prevailing winds.

Bordering the east bank of Spoon river, in Secs. 19 and 20, T. 9 N., R. 3 E., and Secs 24 and 25, T. 9 N., R. 2 E., and farther south in Secs. 10, 15, and 22, T. 8 N., R. 2 E., the till is entirely concealed down to the level of the flood plain by a covering of wind blown material, in some places loess and in others sand. The only evident source of the sand in this region is the adjacent flood plain of Spoon river to the westward, and this sandy alluvium would furnish a ready supply both of the sand and the finer loess material. Observations show that both sand and loess are at present being deposited on the slopes on the east side of the valley by the winds which gather the most of the material from the surface of the adjacent flood plain.

Relations similar to those in the vicinity of Spoon river generally exist between the thicker sand and loess deposits, not only on the bluffs, but also on the more gentle slopes bordering the windward side of the valleys and the areas of flood plains along the Sangamon and Illinois, and the other rivers, as well as many of the smaller streams, in Iowa and Illinois.

Some of the fine material gathered from the flood plain of the river may be carried by the wind for several miles, and this material, together with the dust swept by the winds from exposed portions of the intervening uplands, may be lodged on the bluffs and opposing slopes along smaller streams at a distance from the river and thus supplement the local supply.

The general relations of the loess covered slopes to the direction of the prevailing winds and the possible source of supply of the material together with the lack of any trace of removal or diminution in the quantity of the loess material at the tops of the hills in such places, make it practically certain that the loess occurring on the slopes below the uppermost level of the drift has been mainly deposited by winds since the present, gentle gradient of the slopes was developed, and that it is largely in its original position.

CLIMATAL IMPLICATIONS OF THE LOESS

Wind deposits are characteristic of arid climates, hence some geologists have assumed that arid conditions must have prevailed in the upper Mississippi Valley during the time of max-

imum loess deposition. Leverett[1] thinks that, since loess occurs in a few places between the Kansan and Illinoian drift sheets as well as more generally above the Illinoian and below the Wisconsin till, there must have been two periods of aridity in this region during Pleistocene time.

In his recent paper on the "Solar Hypothesis of Climatic Changes," Huntington[2] has assumed that arid conditions prevailed in the loess area of the Mississippi Valley during each of the stages of glaciation.

However, the following facts make it very improbable that anything like desert or even semi-arid conditions could have accompanied the deposition of the loess:

1. The regularity, or very gradual change, in the thickness of the loess over the uplands. Wind deposits in arid regions are notoriously dune-like and irregular. The level, loess covered prairies of the Illinoian drift plain present none of the irregular features characteristic of wind deposits in arid regions where a dense cover of vegetation did not control the permanent lodgment of the material.

2. The presence throughout the thicker loess deposits of shells of species of land snails that live at present on woodland hills in the same regions, indicates that similar conditions of habitat had existed throughout the time of accumulation of the loess deposits.

3. The absence of glacio-fluvial or other water laid deposits associated with the Iowan drift is also evidence opposed to an arid or semi-arid climate during that time, for under arid conditions the rains would be concentrated during a short season of the year, making the streams more effective in the transportation and deposition of coarse debris.

4. The uniformly fine grain of the deposit, which was derived from sources rich in coarser sand material, also precludes the possibility of arid conditions in which the winds had any greater efficiency than at present. The texture of the main portion of the loess deposits is as fine as that of the uppermost part which was presumably deposited under present climatal conditions in more recent time, and in any exposure there is generally no line or zone in which any change in the texture of the materials of the deposit can be detected.

In the loess deposits bordering the Embarrass and Wabash rivers in Crawford and Lawrence counties, Illinois, a bed of

1. Frank Leverett: Weathering and Erosion as Time Measures. Am. Jour. of Science, Vol. XXVII, May, 1909, p. 361.
2. Ellsworth Huntington: The Solar Hypothesis of Climatic Changes. Bul. Geol. of Am., vol. XXV, No. 4, 1914, p. 577.

typical, yellowish-gray, fossiliferous loess, presumably of the Iowan age, in places rests directly upon the Illinoian drift, and is overlain by 1 to 5 feet of brown, homogeneous silt, the texture of which is similar to that of the lower loess. This brown loess-like clay, which in some places overlies the typical fossiliferous loess, mantles the surface over all of this region, and is thought to indicate a less rapid rate of accumulation of the upper loess, the deposition of this bed being so slow as to permit the complete oxidation of the material while it was being laid down, while the lower oxidized Iowan loess is thought to have accumulated so rapidly that the material did not become so thoroughly oxidized before it was buried. The texture of the material is similar throughout and does not indicate any difference in the power of the winds during the time both phases of loess were deposited.

Evidence of the lack of conspicuous flooded conditions of the streams attending the melting of the Iowan ice sheet, is clearly seen in the lack of association with this drift sheet of outwash deposits, gravel trains, eskers, and other glacio-fluvial features, associated as compared with the abundance and extent of such water sorted deposits in association with the Wisconsin till, or with the earlier Kansan and Illinoian drift sheets. This absence is doubtless due to the very slow rate of melting of the Iowan glacier, which slow rate of melting probably resulted from the prevalence of a somewhat unusually low temperature in the region during the melting of the Iowan ice sheet, and was not due to the existence of arid conditions during this time.

The loess deposits demand a climate so nearly like that of the present that the hills and uplands were covered with vegetation practically as today; that the winds were no more efficient in gathering or transporting materials than at present; that the land snails could live on the same forest covered hills which they now inhabit. These facts, together with the general lack of glacio-fluvial deposits associated with the Iowan drift are not consistent with arid conditions. It seems to the writer they can be better explained by assuming a slightly lower temperature during the melting of the Iowan ice sheet than attended the melting of the other ice sheets of the Pleistocene period, and continuation of this low temperature for a considerable time after the withdrawal of Iowa glacier, such as would retard for a time the establishment of vegetation upon the Iowan drift surface, and also delay the renewal of vegetation over the mud flats of river flood plains after they were overflowed by the streams.

Papers on Botany

A COMPARISON OF CERTAIN ROCKY MOUNTAIN GRASSLANDS WITH THE PRAIRIE OF ILLINOIS

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Grasslands occur at varying altitudes in mountain regions and are almost as widely distributed as the peaks and ranges themselves. Alpine and sub-alpine meadows are perhaps best known, but in them the preponderance of other herbaceous and low woody plants over the grasses is such that the fitness of the term grassland may well be questioned. At somewhat lower altitudes, particularly in the zone immediately below the sub-alpine and commonly known as the "montane," are found treeless areas that better deserve the title of grasslands. At times the transition from the forest is a gradual one, through areas of savanna in which trees are scattered at rather wide intervals over grass-grown fields. Such grasslands and savannas are a well marked feature of the eastern slopes of the Rocky Mountains in Colorado, and are also found in other neighboring states. From their open park-like planting they are popularly designated "parks." One of the best known is Estes Park, some 60 miles northwest of Denver, included within the limits of the recently created Rocky Mountain National Park.

It was the writer's privilege during the summer of 1914 to visit this Park with a class of students in field ecology and also to study for some weeks a smaller mountain grassland, known as Boulder Park, from South Boulder Creek, a small stream traversing the park from west to east. Boulder Park is 47 miles northwest from Denver upon the Moffatt Railroad, has an altitude of 8880 feet, is two and a half miles long, nearly a mile wide, and contains the little village of Tolland. On account of the richness and variety of its vegetation it was recently chosen by the University of Colorado as the site of its Summer Mountain Laboratory.

The grassland here occupies the floor of a mountain valley broadened by glacial action and partially filled with the gravels of terminal and lateral moraines. These gravels have been worked over so as to give the valley a comparatively level floor upon which South Boulder Creek meanders in broad curves, the channel often widening into shallow ponds on account of the low gradient assisted by the work of beavers. Two other shallow ponds or small lakes are drained into the creek. The stream has intrenched itself but little and the general appear-

ance of the valley floor is not unlike that of the lake plain which succeeded the ice sheet in the Chicago region and is at present partly occupied by edaphic prairie. It therefore seems that it would be interesting to compare the conditions which have produced grasslands in these two areas, situated in rather widely removed regions and differing in so many respects. It may be possible that such a comparison may so stimulate inquiry that further research along this line may contribute something to the general problem as to the factors that are efficient in producing this type of vegetation. A full analysis of the composition of the vegetation is not possible nor is it either desirable or necessary, for it has already been rather completely done by Ramaley[1], Robbins[3], and others connected with the Colorado Mountain Laboratory.

CLIMATIC CONDITIONS

As already indicated the prairies of Illinois and the mountain grasslands of Colorado now under consideration, differ rather more than 8000 feet in altitude, and this brings a corresponding difference in temperature. The mean summer temperature of Boulder Park is about 15 degrees F. lower than that of the Chicago Region, only about six weeks of midsummer are usually free from frosts and a drop in temperature below the freezing point has been known to occur during almost every week of the year. There is almost no growth before June first, and very little after the end of August, thus making a short vegetative season that almost entirely eliminates annuals from the mountain habitat. Winter temperatures also differ somewhat, but probably not enough to materially affect vegetation, at least it may be said that this mountain park is no colder than many prairie regions, such as those of the Dakotas.

In humidity the two regions are probably closely comparable, although no accurate data are available from Boulder Park, where, in spite of the light showers that are an almost daily occurrence during a considerable portion of the summer, the mountain air is quite as dry as that of Illinois during the summer months. The amount of precipitation in the two localities is of the same order of magnitude, Illinois, (about Chicago) averaging a little over 30 inches and Boulder Park a little less than that amount, per annum. Curiously enough snow never accumulates to any great depths nor does it usually remain long in this valley, probably on account of

the long slopes which lead directly down to it from the Continental Divide, here some 2500 feet above it, but less than ten miles distant.

Both localities are exposed to high winds, but the mountain habitat particularly so. During the colder months of the year in particular do westerly winds of high velocity and great desiccating power sweep down from the Continental Divide.

SOIL CONDITIONS

The soil conditions are very diverse. The rich agriculture of Illinois is associated with a prairie soil of almost exhaustless fertility. It is a dark, heavy loam or silt of rather fine texture, possessing, as has been shown by Harvey[3], a large water holding capacity as indicated by a high wilting coefficient. On the contrary, the soil of Boulder Park is lacking in fertility and coarse in texture, consisting of glacial gravels with a very small percentage of humus. No determination of its water holding capacity nor of its wilting coefficient have been made, but they are known to be low, since investigations of actual soil moisture conditions by Ramaley[4] show, during July, from 1.5 to 5.5 per cent of moisture in the drier portions, and only 11 per cent of moisture in the soil of the mesophytic meadow. In and about the shallow lakes there are small accumulations of peat and in portions of the sedge-moor the accumulation of humus has been rather considerable, so that in spots the soil becomes comparable in its organic content with that of corresponding areas in Illinois.

It seems certain that during the summer season the soil of this mountain habitat, except where it is at or near the water table, is deficient in soil moisture and this deficiency is reflected in the xerophytic aspect of its vegetation. It is interesting to note in this connection that Harvey[3] has found that the soil moisture in the Chicago prairie falls below the wilting coefficient at midsummer.

Summarizing the comparison of climate and soil factors in the two grasslands it will be seen that they differ widely in respect to altitude, length of growing season and in soil fertility and texture, but agree in possessing conditions of relatively low atmospheric humidity, in being exposed to high winds and in having a deficiency in the supply of soil moisture at least during the weeks of midsummer. Further the precipitation in the two habitats is practically the same in amount, although a closer study would probably show that it

differs considerably in its distribution in relation to the growing season.

Both habitats have been subject to fires and it seems possible that fire may be a factor affecting to some extent at least the development and maintenance of grassland conditions. The arguments for its effectiveness in Illinois need not be discussed here and it may only be said that in the Rocky Mountains near the valley which was the site of these observations, where there had been repeated fires, the development of tree seedlings, seemed to be a slow and difficult matter.

THE PLANT SUCCESSIONS

In comparing the character and order of the development of the vegetation of the two grasslands the writer will limit himself to that portion of the Illinois prairie with which he is most familiar, that is, to its occurrence in the Chicago region and will also omit all but the necessary facts regarding this vegetation since they are already available in the reports of Cowles[8], Harvey and others. It will be necessary, however, to give rather more details regarding the Colorado mountain grasslands.

In both there is a well marked hydrarch succession of associations proceeding, in the Chicago region, from filling of the shallow lakes which followed the recession of the glacial Lake Chicago and which still persist in the form of larger and smaller bodies of water of which Calumet and Wolf lakes are examples. Very similar shallow lakes are found in Boulder Park as exemplified by Park Lake. The culmination of these successions is, in both regions, a rather mesophytic grassland that may very conveniently be designated prairie-meadow to distinguish it from the other associations of the series. Our present knowledge seems to point to this as the only manner of origin of the prairies of the Chicago region and as the usual course of development of most of the grasslands of Illinois, but in the Colorado mountain parks there is also a xerarch succession leading from the bare glacial gravels in a well marked series of associations slowly culminating in the same or a similar more mesophytic prairie-meadow.

THE HYDRARCH SUCCESSION

In the mountain parks of Colorado small shallow lakes are not uncommon, some being due to "kettle hole" origin at the time of the recession of the glaciers. Two of these, known

as Park and East lakes, are found in Boulder Park and having been rather carefully studied the succession, may be taken as representative of that of this class of mountain lakes. The soil at the bottom and shores of the lake consists of the original glacial gravels with a very small amount of alluvium carried in by tributary streams, and a larger or smaller amount of peaty vegetation. The waters are nearly stagnant on account of the small amount of run-off from surrounding areas. The larger of these lakes is only about 3 to 4 feet deep, and the other but little deeper, the conditions being similar to such shallow lakes of the Chicago area as Wolf and Calumet. It would therefore be expected that the same associations would be represented in the two regions especially as no vegetation shows a wider distribution or greater uniformity than aquatic and sub-aquatic associations, and in fact the same type of succession is actually seen but with several notable differences.

The algal association in the mountain lakes instead of being abundant and varied as in Illinois, seems to be made up of a comparatively small amount of two species of *Spirogyra,* some *Chaetophora* and *Drapernaldia* and a few blue-green algae of small size. It seems safe to say that there is not more than 20 per cent of the mass or number of species of algae found as in similar shallow water in Illinois. The other submerged aquatic community may be termed the Myriophyllum-Batrachium association, from the two species *Myriophyllum spicatum* and *Batrachium trichophyllum,* its only members. The latter is the more abundant, but the mass of the two is small compared with the submerged aquatics of more eastern waters.

Separated from the associations already mentioned and occupying the shallow water near the shores is the main aquatic community, a pondweed association, characterized by plants with ribbon-like submerged and floating leaves. Its dominant member is a bur-reed, *Sparganium angustifolium,* whose leaves float on or near the surface, and *Potamogeton lonchitis* and *P. foliosus.* This paucity of forms contrasts with the conditions in Illinois where at least twice as many species and double the mass of vegetation are to be found in the corresponding habitat. The mountain lakes are also deficient in the entire absence of any association corresponding to the water lily or cat-tail associations, but the submerged and floating leaves of the pond-weed association are followed at once by the emergent sedges. Perhaps nowhere do the two regions resemble each other more closely than in this stage of the succession known as the sedge swamp, fen, or sedgemoor. It is

true that many of the species are different but the same genera are present, and, what is more important, the ecological types are the same and the association occupies the same place in the succession.

In the Colorado parks this is often one of the most extensive associations in its extent and apparently is of rather prolonged duration. Several undetermined mosses are rather abundant upon the soil, but the initial and most abundant seed plant is *Carex utriculata,* soon mixed with *C. variabilis, C. lanuginosa, Eleocharis tenuis,* and such herbs as *Caltha rotundifolia, Sedum rodanthum, Montia chamissonis* and *Spiranthes stricta.* As soil formation advances and the drainage gradually develops, bringing the soil surface well above the ordinary water table, the change is marked by the invasion of *Carex festiva,* and many of the grasses of the succeeding grassland. It is, however, a noticeable feature of the grassland that many of the pioneers of the sedgeswamp persist in the meadow, a condition not uncommon also in the low prairie of Illinois.

Following the sedges is the main grassland community, termed the meadow association in the mountains, but corresponding directly with the prairie grassland of Illinois. In aspect the two agree closely, the bulk of vegetation being rather coarse grasses mingled with many herbaceous plants of other habits of growth. In both the other herbs outnumber the grasses in species, the mountain grassland abounding in species of *Eriogonum, Cerastium, Thalictrum, Potentilla, Geum, Epilobium, Gentiana, Pentstemon, Galium, Astragalus, Carduus, Senecio* and *Erigeron.* In many parts of the grasslands the limits of this meadow association may be determined by the distribution of *Erigeron macranthus,* a species that seems to be a certain indicator of the degree of mesophytism characteristic of this meadow. From the evidence at present available it is impossible to decide whether such a meadow is the true climax of these mountain parks, but it is certain that it persists for long periods and occupies the most mesophytic habitats outside the forests. In it the soil has the best development of humus and possesses the best water supply and in it is seen the greatest luxuriance of plant life, including a considerable number of species from the associations immediately above and below it. From the sedge-moor come *Carex festiva* and *C. variabilis, Calamagrostis canadensis, Deschampsia flexuosa, Koeleria cristata and Beckmannia erucaeformis,* while among the more mesophytic of the dry-grass species which intrude, are *Stipa comata, Festuca pseudovina* and several of

the more mesophytic species of *Muhlenbergia and Agropyron.* Among the more abundant grasses are several species of *Poa, Agropyron, Agrostis, Deschampsia, Phleum* and *Bromus,* the last mentioned genus being particularly abundant wherever there is a contact between the forest and grassland.

THE XERARCH SUCCESSION

The porous condition of the glacial gravels, which form the greater portion of the soils of Boulder Park and similar montane areas, provide such excellent natural drainage that with the recession of the mountain glaciers large areas of these gravels must have been left without vegetation and with surface but little more inviting to plants than the bare rock. At present these gravels are seen upon the mountain slopes, the ridges representing lateral and medial moraines and in the irregularly placed terminal moraines. More level areas probably represent the gravel bars of glacial streams. Upon the dry suface of these soils lichens appear to have played a comparatively small part in the establishment of vegetation, probably on account of the instability of the surface particles during high winds. Still crustose and foliose lichens are fairly abundant upon the larger boulders. The most important pioneer plant appears to be *Selaginella densa* forming mats over and between the coarse soil particles. It is closely followed by the succulent *Sedum stenopetalum* and several xerophytic grasses growing as crevice plants. The mat forming habits of the *Selaginella* prepares the soil for the other pioneers, among which *Antennaria parvifolia, Arenaria Fendleri, Chrysopsis villosa, Orthocarpus luteus, Carex stenophylla* and *Commandra pallida* are conspicuous. The constant presence and predominance of the first mentioned xerophyte would make it appropriate to term this pioneer vegetation the "Selaginella association." It is characterized by low growing perennial plants, a large percentage of bare ground and very slow advance towards a less xerophytic condition. This slow advance is largely due to the low water content of the soil, due to its coarse texture and to the extreme slowness of the humus accumulation. High winds dry the dead vegetation, break it into fragments and carrying it off, leave almost nothing to form humus, while the little that may be formed is still liable to be removed by the same agency in the form of dust. The finer soil particles, resulting from the disintegration of the gravel, are aften lost in the same manner. The mat forming tendency most evident in the *Selaginella* and the habits of vegetative reproduction in such plants as the *Carex* and *Commandra*

finally increase the amount of vegetation and make the entrance of new species an easier matter.

The succeeding community may be called the Carex-Artemisia association from the comparative abundance of *Carex stenophylla, C. filifolia, Artemisia frigida* and *A. canadensis.* Grasses also begin to be rather conspicuous, being represented by species of *Festuca, Muhlenbergia* and *Koeleria.* The mat-forming habits of several of these grasses is of the greatest importance because only within such mats does the formation of humus occur, and with it the advance of the association. Even in this association not more than one-half the surface is actually covered by the vegetation. About this time the invasion of other species in small communities giving a patchy character to the vegetation becomes conspicuous. Such aggregations are found of all species, but among the more conspicuous may be mentioned those of *Antennaria parvifolia, Campanula rotundifolia, Potentilla* spp., *Aragallus Lambertii, A. Richardsonii,* and *Achillea millifolium.*

The succeeding stage is well developed and is perhaps the most usual vegetation of the montane parks. It is characterized by the greater development of grasses in comparison with other herbaceous species and has been designated by Ramaley, who has studied it most extensively, the "dry grassland." From a study of the composition of a large number of permanent quadrats Ramaley finds that there is still much bare ground, amounting to about 25 per cent of the whole area during the month of July. The same investigator reporting upon the composition of the vegetation finds 30 per cent of it composed of various species of grasses, species of *Muhlenbergia,* making up 8.18 per cent, and of *Festuca* 7.78 per cent. *Carex* spp. amount to 11.25 per cent and *Aragallus* spp. to 9.68 per cent, while *Selaginella densa* still covers more than 5 per cent of the whole area. Among the more common species are *Agropyron violacea, Festuca octoflora, F. pseudovina, Koeleria cristata, Poa* spp., *Muhlenbergia gracilis, M. Richardsonis, Stipa comata, Carex filifolia, Potentilla Hippiana, P. gracilis, Aragallus Lambertii, A. Richardsonii, Artemisia* spp. and *Pentstemon procerus.* Other species are rather numerous and some become locally abundant while it is to be noted that all the species of the pioneer associations persist. There can be no doubt that this dry grassland association in its various modifications is a comparatively permanent vegetation and it is even possible that it is the climax for the more exposed situations, altho a rather careful examination leads to the conclusion that it is gradually advancing in mesophytism largely through

the mat and tuft habits of many of its grasses. This is accompanied by a slow addition of humus to the soil, improving its water-holding capacity, and this in turn reacting to cause a closer stand of vegetation. This transformation seems gradually to advance this succession to a more mesophytic association differing from that described as the climax of the hydrarch succession principally in the smaller amount of such species as *Carex festiva* and other secondary species of rather decidedly hydro-mesophytic character. Most of the grass species of the dry grassland association are still to be found, but the more xerophytic in decreasing abundance. The quantity of *Poa Muhlenbergia* and *Stipa* has increased and such forms as *Deschampsia, Agropyron, Danthonia, Poa* and *Avena* have come in. The grasses now show a greater predominance over other herbaceous plants although several new ones appear among the latter, the most conspicuous being *Erigeron macranthus* that seems to be a rather constant indicator of mesophytism. As previously noted this prairie-meadow association has a great variety of species, many showing peculiar local abundance, but unfortunately neither the extent of our investigations nor the space at our disposal permits their discussion in this paper. No more noticeable evidence of advancing mesophytism can be given than the data of Ramaley that the bare ground in the prairie-meadow is not more than 10 per cent of the total area and that it is often entirely absent. The question of the possibility of a forest invasion of these grasslands seems quite as far from settlement as that of the relationship of grassland and forests in Illinois and can not be discussed at present further than to remark that while the Colorado mountain grasslands show much evidence of great permanency, indications are not lacking that they are areas of potential forests and show the invasion of trees at certain points.

SUMMARY

From the preceeding rather superficial observations the following agreements and differences may be noted as existing between these Rocky Mountain grasslands and the prairies of Illinois, as seen in the Chicago region:

Agreements

1. The two regions have very similar conditions of rainfall and humidity and in both there is a midsummer deficiency in soil moisture.

2. In both there is a well marked hydrarch succession passing from the aquatics through the sedge-moor in a closely comparable series of associations.

3. Both possess a climax prairie-meadow association in which herbaceous species other than grasses are fairly abundant.

Differences

1. The two regions differ much, as has been shown, in altitude, in temperature, in length of growing season and in character of soil.

2. The mountain region is distinguished by the greater paucity of aquatic species.

3. The mountain region exhibits a xerarch succession comparable to nothing found in Illinois.

The writer gratefully acknowledges his indebtedness to two of his students, Misses Nellie C. Henry and Minnie C. Frost, for much of the data used in this paper.

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STUDIES IN PHYLLOSTICTA AND CERCOSPORA.

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During the years 1912 and 1913, while Dr. F. L. Stevens was dean of the College of Agriculture and Mechanic Arts in Porto Rico, he made extensive collections of parasitic fungi. When he came to the University of Illinois, he donated this collection to the University. In my studies I have made use of this material, working chiefly on the two genera Cercospora and Phyllosticta, both of which belong to the group of Imperfect Fungi.

The genus Cercospora of about 700 species, contains many important parasites, chiefly causing leaf-spotting. The spots are variable in size and color, often bordered by a narrow reddish or purple margin, with a sordid-white center due to the fungal hyphae which penetrate into the leaf. The spots are usually definite, though in some instances indefinite, or even lacking when the leaf is covered with a smoky brown mass. If conditions are such that growth is abundant, the spots become hoary, due to the large number of spores. The fruiting bodies are conidia which are borne on the ends of hyphae or conidiphores, which vary in number and size, may be simple or branched, and are brown in color. They are often abruptly bent at the point of spore production, and thus conidial scars are left. Conidiophores are usually fasciculate, and may arise singly or in numbers from the stomata of the leaf. As a rule, they vary in length and septation with age. The conidia are hyaline, several septate and they vary in size and shape. They are usually elongate, clavate or fusoid, straight and sometimes attenuate at the end farthest from the conidiophore. Each cell of a conidia is capable of germination, and very often when spores fall on a leaf, they produce germ-tubes which infest the host through the stomata. Very few cross inoculations have been made, and, little is really known concerning the limitations of the species. When the host plants are different, minor variations in size, color, septation, etc., of the conidia and conidiophores, or in the macroscopic appearances of the spots are generally employed in distinguishing species.

The genus Phyllosticta is very large, comprising nearly 1200 species, only a few of which have been determined by comparison or cultural studies. These forms produce leaf spots which may be circular, angular or indefinite. This genus differs from Phoma in that it inhabits only the leaves, while the latter may spread over the fruit, twigs or stems, also in that Phoma never produces a definite spot. The leaf blotch

caused by Phyllosticta is due to a weakening or killing of the leaf-tissue by the mycelium, which spreads throughout the leaf. When conditions are favorable, the spots develop rapidly and the greater part of the leaf from the margin to the mid-rib may become involved. Sometimes the spots are brown, giving the appearance of sunburn, or again they may be of yellowish color, or sordid-white, or perhaps gray, with a reddish-purple margin which may be concentrically zonate. The center of the spot often falls out, and eventually, when affected to such an extent that they can no longer function, the leaves fall, thus weakening the vitality of the tree. Instead of being borne on conidiophores as in Cercospora, the conidia are produced in pycnidia. They are usually on the upper surface of the leaf, though sometimes below, and appear as tiny black specks when large enough to discern with the aid of a lens. They may occur singly or in clusters, and may be immersed, erumpent or superficial. When immersed a beak pierces the epidermis, thus facilitating the escape of conidia. The pycnidia are lenticular to globose, usually brown or black, opening by a pore or ostiole which is often dark-bordered. The conidia are hyaline, usually ovate to elliptical, though sometimes spherical, and they vary in length from 2 to 60 μ. The perfect stage of this fungus is known in but few cases.

It has been the custom when creating new species to designate as new those forms which have never been reported on the particular host or any genus of the same family, and which are distinct from any form on a related host. In working over some 50 different forms, I have found 15 which are distinctly new species. However, I am somewhat hesitant to describe these as Phyllostictas, rather than Phomas, since I believe there is no tenable distinction between these two genera. They are alike in conidia and pycnidia, and these parts seem to me to be the most characteristic. The general nature of the spots cannot serve as distinguishing features since they are both definite and indefinite on the leaves, nor does it seem justifiable to make the location of infection of a plant a basis for distinguishing species.

A METHOD OF PROPHESYING THE LIFE DURATION OF SEEDS

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Since former explanations of the loss of vitality of seeds in storage conditions have proven incorrect, we have been led to surmise that a gradual coagulation of the proteins in the embryo may offer such an explanation. It has been shown by Chick and Martin[1] that proteins do not have a fixed temperature point for coagulation, but that coagulation may occur at any temperature provided the time of exposure be sufficiently great. Buglia[2] has applied the following time temperature formula to protein coagulation: T=a-b log Z, in which T= temperature cent., Z=minutes of exposure, and *a* and *b* constants. Lapeschkin[3] applied this formula to the coagulation of proteins in active plant cells and found a close agreement in theoretical and found values where time duration was short.

In this investigation constant temperatures were obtained by the use of the thermostat shown in figure 10. An external water bath contains a vessel of smaller dimensions which is connected with a water-cooled reflux condenser. Mixtures of ethyl and methyl alcohol and water used to provide desired temperatures and the seeds, in closed test-tubes, are suspended through closed perforations.

After quantities of seeds were exposed to a given temperature for various lengths of time, they were sterilized in an aqueous solution of silver nitrate and placed in sterile petri dishes for germination. Daily records were kept as in table I. Increased time of heating shows a delay in germination as well as a fall in germination percentage which is also true of seeds stored for a long time at room temperature.

Table II shows the life duration at various temperatures as found by experiment and the calculated life duration according to the formula. The constants *a* and *b* were found by the method of least squares from the found values of T and Z, and from these T was calculated for the various values of Z. The found values agree quite closely with a curve plotted for the theoretical values.

The temperature coefficient of life duration of wheat is found to be 7 or 8 for each 10 degrees change of temperature. Goodspeed[4] working with barley found a coefficient of life

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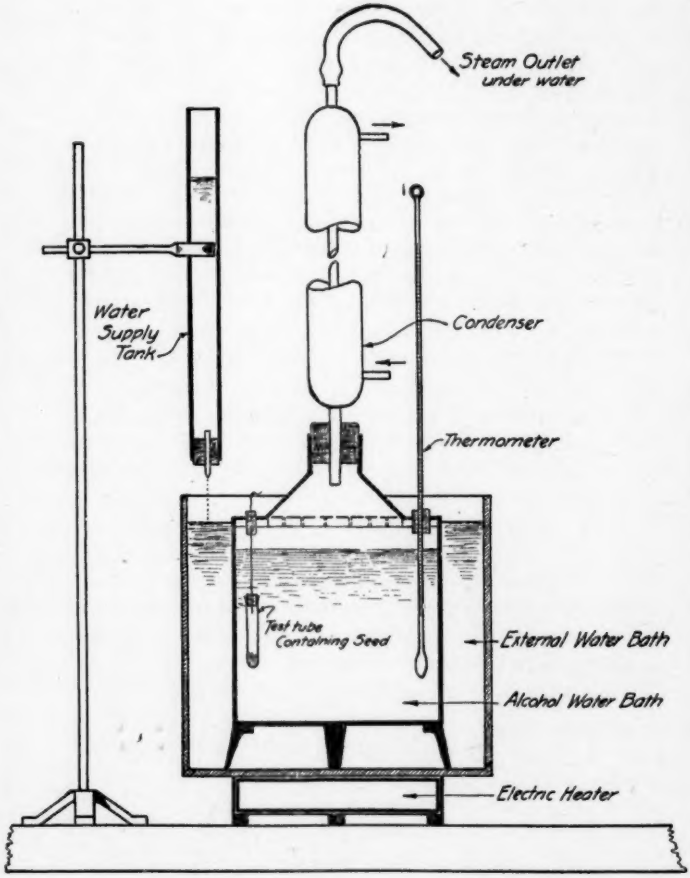

THERMOSTAT FOR HEATING SEEDS

Figure 10

duration of about 11, but since he did not control the water content, we are not justified in making a comparison. Loeb[5] working with sea urchin eggs found a coefficient of 500 to 1,000, while Moore[6] working with hydroids found a coefficient of about 1,000. The high water content in these cases probably materially affects the value. It should be noted that we are not dealing with a homogeneous system, but with a colloidal system and that it is not remarkable that the Van't Hoff temperature law for the rate of reaction does not apply.

Since here is a close agreement between the calculated and found values it seems probable that the time temperature formula for protein coagulation can be applied as a formula for the temperature-life duration for seeds. In order to establish the general application of this principle much more work is needed and several influencing factors are to be considered as here-to-fore outlined by Crocker and Groves[7]. The work shows possibilities of throwing light on the nature of the process of loss of vitality in seeds and of leading to a quantitative statement of the significance of various storage conditions, especially moisture content and temperature, upon the longevity of seeds.

This work was done under the direction of William Crocker, University of Chicago.

TABLE I

RECORD SHEET NO. 21, TURKISH RED WHEAT

Temp. 87.5. Moisture 12%, April 10, 1914.

Time in days	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Control	0	2	2	4	3	3	0	0	0	0	0	0	0	0	0	0	0	0
	92	92	92	93	95	95	98	98	98	98	98	98	98	98	98	98	98	98
7 min.			0	15	12	7	8	7	8	7	5	3	3	4	4	4	3	2
..			2	5	27	41	49	55	61	64	67	70	72	72	72	72	73	74
8 min.					4	8	8	7	8	7	5	3	1	5	1	1	1	0
					5	10	25	30	35	41	47	52	54	54	58	59	59	60
9 min.						2	4	4	5	4	5	4	5	2	3	6	5	4
						2	4	8	10	11	18	25	28	32	34	35	37	38
10 min. (Percent partially germinated										1	3	4	6	4	3	3	4	5
(Percent Germinated										0	0	0	0	4	5	9	11	11
11 min.												1	1	0	0	1	2	1
												1	1	2	4	4	4	5
12 min.													2	2	2	2	2	2
													0	0	0	2	2	2
13 min.																0	0	0

5. Archiv. Ges. Physiol. 124:411.
6. Archiv. Entiv. Mech. 29:145-287.
7. Proc. Ntl. Acad. of Sci., Vol. I, p. 152, 1915.

TABLE II.

GERMINATION RECORD TURKISH RED WHEAT

Theoretical temperatures calculated by formula: T=a-b log Z.

Notation: T=Temperature, Z=Time in minutes, a and b are constants.

Value found for a—98.88. Value found for b—11.78.

Trial No.	Duration in Minutes	Found Temperature	Calculated Temperature
A	7	89.2	88.9
B-C	8	87.7	88.2
D-E-F	9	87.5	87.6
G	10	87.5	87.1
H	15	84.4	85.0
I	18	84.4	84.1
J	45	78.9	79.4
K-L	50	79.1	78.9
M	50	78.5	78.9
N	120	75.8	74.4
O	315	71.3	69.5
P*	8 years	20	20.9

*Data from White's Experiment. Proc. Royal Soc. London, 81, 417, 1909.

PECULIAR EXAMPLES OF PLANT DISTRIBUTION A PROBLEM IN PHYTO-GEOGRAPHY

H. S. PEPOON, LAKE VIEW HIGH SCHOOL

ABSTRACT

Based upon the collection of 1800 species in the Chicago area, 1000 species in Fulton county, and 900 species in the driftless area of Jo Daviess county, the author cites numerous examples of peculiar or unique distribution of plant species, many of the examples being "extra limited" as far as the printed record presents the assigned localities.

He endeavors to group these examples under four main causative agencies that may be tabulated in the order of their increasingly greater numbers of representatives, as follows:

a. Aboriginal plantings.

b. Vestigial forms of glaciated times.

c. Extension outpost forms.

d. Survivals of destruction by human agency.

Some 50 species are named in the discussion and the author invites friendly criticism and further enumeration of examples.

THE GRASS FLORA OF ILLINOIS

EDNA MOSHER, UNIVERSITY OF ILLINOIS

The grasses of the State have been listed several times in connection with various published floras of the State, but as far as I know only one paper has been devoted solely to this subject. This is a paper by I. A. Lapham of Milwaukee, who in 1857 listed and described 50 genera and 114 species of grasses, excluding those cultivated for grains. He also published a flora of the State in the same volume of the Transactions of the Illinois State Agricultural Society. Additions to this list were made from time to time by Dr. Brendel, M. S. Bebb, S. B. Mead and Dr. Vasey. The first extensive local flora was published by H. H. Babcock of the plants found around Chicago. He listed 58 species of grasses. H. N. Patterson of Oquawka published a flora of the State in 1876, in which he included 52 genera of grasses and 124 species. In 1878 W. C. Flagg compiled from these previous lists a flora of Illinois, having in addition some material collected by Dr. Burrill and others in the vicinity of the University. He included 55 genera and 139 species of grasses, which is probably the largest list of grasses of the State up to the present time. There have been a number of other local lists published. Some of them contain very few grasses. The most important of the local lists are Dr. Brendel's of Peoria, in 1887, including 70 species of grasses, a flora of Cook county by Higley and Raddin, including 85 species, and a flora of LaSalle county by Huett with 79 species. In undertaking to work over the grass flora of the State, the collections of the previously mentioned writers have been consulted as far as possible.

The University of Illinois has many specimens collected by Mead, Webb, Vasey, Hall and Patterson, beside the entire collections of Dr. Brendel of Peoria, Dr. Schneek of Mt. Carmel, and Dr. Welsch of Mascoutah. The later collections of V. H. Chase of Stark county, F. E. McDonald of Peoria, and Chas. Robertson of Carlinville, contained many interesting species. The Field Museum in Chicago contains Patterson's entire collections with many others collected by Wolf, Mead, Bebb and others. Babcock's herbarium is at Northwestern University and has been consulted, but the entire collections of Dr. Vasey have not been seen nor that of Prof. E. J. Hill of Chicago, who has made some new records for the State.

A careful study of this material succeeded in verifying 125 out of the 139 species mentioned in Flagg's list, which includes practically everything mentioned by other authors.

There are in all, 22 species reported from Illinois of which no authentic material has been seen. Some of these are reported in Gray's Manual and Brittain and Brown's Illustrated Flora as occurring in Illinois, but no Illinois specimens are found either in the Gray Herbarium, the New York Botanical Garden, nor the herbarium of the U. S. Department of Agriculture. Many of these were plainly wrong determinations, but others may yet be found when more material is examined.

Of the 125 species mentioned in Flagg's list there are 25 species introduced from Europe. My own list at present contains 187 species, of which 36 are introduced, making 62 species more than have been reported in a State list up to this time, or an increase of 50 per cent. It will perhaps be interesting to consider for a moment where these 62 new species have been obtained. As is well known, the majority of species in our Illinois flora belong to genera which are most abundant in warmer climates and of our 151 species native to Illinois, two-thirds belong to genera which are most abundant in the southeast and some are also found in Mexico. Nearly all of our species found in sandy or very dry soil have such an origin, and these, for the most part, are confined to such areas throughout the State. Apparently they have spread from one sand area to another, but of that we have no certain knowledge. Such are most species of the genera Sporobolus and Aristida, some Panicums, certain Eragrostis species, Triplasis purpurea, Cenchrus carolinianus and many others. Of the remaining third we have a large number which are found all over the eastern United States, such as Andropogon scoparius, Seersia oryzoides, Festuca octoflora and others. In the northern part of the State, particularly around the lakes, we have several species which are more abundant to the north of us, such as Phalaris arundinacea, Ammophila arenaria, Bromus Kalmii and others. We have very few typically western forms, probably our Bouteloua species are more so than any others in our grass flora.

Of these 62 species not included in the earlier lists 9 are species introduced from Europe. These include *Bromus incanus* and *tectorum,* the latter of which is spreading very rapidly in the State, *Lolium tementulum* or bearded darnel, *Hordeum nodosum, Panicum miliaceum,* the old world millet, *Arrhenatherum elatius* or tall oat grass, *Helochloa schoenoides* and *Sorghum halapense* or Johnson grass, which has

been cultivated in the south and has been found in various localities in the state and as far north as Chicago. A few species have apparently come into Illinois from neighboring States, and the most remarkable fact is that most of them come from the west. Among these are *Agropyron tenerum* and *Smithii, Bromus pumpellianus, Sporobolus asperifolius* and *Hordeum Pammeli.* Another *Argropyron* species, *dasystachum,* has come in from the north, while the south has given us *Agrostus Elliotana, Muhlenbergia capillaris, Sporobolus clandestinus* and *Eragrostis Wiegeltiana.* Most of these have never been reported from the State. The majority of new species, however, has come from revision of material collected by the early botanists, a great deal of which had not previously been determined. The genus Panicum has made the greatest gain as to number of species, now including 34 instead of 9. These have all been published by Hitchcock and Chase in their revision of the genus. The genus Sporobolus gains 7 new species, Paspalum 4, Aristida 2, and Poa 2. Of the Poas one is the rare species *P. wolfii,* the type of which was collected in Illinois, the other native species, *P. Chapmaniana,* which resembles the introduced species, *P. annua,* so much that they are usually all labelled *annua* in the various collections examined. Dr. Brendel, Peoria, had noticed the difference, however, and his specimens of *Chapmaniana* were all unnamed with a note "A Poa with the habits of *annua* and the spikelets of *pratensis,*" which is a very good definition of the species.

There have been many species collected in adjoining States very near the boundary lines which may occur in Illinois now, but have never been collected. In fact, there are representative collections from very few counties in the State and from nearly half the counties there are no specimens at all. It seems quite probable, with further study of the material in existence and with new collections which may be made, that the number of grasses now occurring in Illinois, or that have occurred here, may be very materially increased.

A FLORIDA SMUT, USTILAGO SIEGLINGIAE, IN ILLINOIS

MARGARET MEHLHOP, UNIVERSITY OF ILLINOIS

While in Havana, Illinois, the latter part of last November, I collected a few grasses at a place locally known as Devil's Hole. It is a small area on which the sand dunes are so active that it cannot be used for cultivation. There grow here the xerophytic plants and bunch grass associations which are characteristic of typical blowouts. A point of peculiar interest regarding this region is that the animal life as well as the plant life is similar to that of the southwestern States[1].

In our study my classmate and I became interested in a grass which at first glance we thought was a dwarfed form belonging to the genus Sporobolus, but a careful examination of the spikelets gave indications that it was Triplasis purpurea (Walt.) Chapin. However comparison with herbarium specimens from the same county showed that although the less evident but more important characteristics were similar, the superficial but more apparent ones were not. Our conclusion was confirmed by the examination of a smut growing in the ovaries, the identity of which was determined by Dr. Wm. Trelease. It proved to be Ustilago sieglingiae[2] Ricker, which uses Triplasis purpurea as a host, but has been collected only from Punta Rassa, Florida[3]. Examination of such periodicals as "The Journal of Mycology," "Just's Botanischer Jahresbericht," and "Phytopathology," gave no evidence that it had been reported in any other region.

A careful comparison was made between the spores of the material found in Havana and those of the type material, a small amount of which Dr. J. J. Davis obtained from the herbarium of the department of plant pathology of the University of Wisconsin, and kindly sent to Dr. Wm. Trelease. They were similar in all respects, except size, the type spores seeming

to be smaller. Exact measurements proved that the extremes in size are the same in both cases, the smallest being 3 μ by 4μ and the largest 4.5 μ by 6μ, but that the average size of the type spores (3.53 μ by 5.16 μ) is slightly smaller than the Havana material, (6.56 μ by 5.4 μ).

Apparently the specimens of Triplasis purpurea attacked by the smut are different from those which are not. They are only one-third as tall as the herbarium specimens, but are more freely branched; the internodes are so shortened that the sheathes overlap; the panicles are all partially or wholly enclosed in the sheathes instead of the largest ones being long exserted; the spikelets are somewhat larger; the ovaries have developed into rather large ergot-like bodies about 4 mm. long and 1.5 mm. in diameter, and the glumes, lemmae, and paleae are membranous and paler in color, but the number, shape and arrangement of these flower parts are the same.

However, these differences are not all due to the action of the fungus. It will be remembered that the collection was made late in the fall. Enclosed and cleistogamous spikelets are characteristic of late specimens in the genus Triplasis, including Triplasis purpurea[4]. This would account for the lack of exserted panicles and probably for the difference in texture of the flower parts. But the abnormal development of the ovaries is entirely due to the fungus.

In order to understand the occurrence of Ustilago sieglingiae in Havana we must consider its geography. It is situated in a sand deposit in the midst of a broad glacial flood plain. Its geologic conditions are therefore local, so that the smut must have reached it by transportation through short distances from sand patch to sand patch. It is surprising then, that it has not been collected from some sand area intervening between Punta Rassa and Havana, two places in which the meteorological conditions are very different. If, as is possible, it attacks only the autumnal forms of its host, it has probably not been obtained from these other localities because collectors have searched for it earlier than it appears. We believe that it can be found in such regions when the conditions are the

same as those under which our material grew. Next summer and fall, if I can secure more material, I shall continue this study in hopes of getting confirmation of the thought I have advanced, or of getting new light on the subject.

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Papers on Zoology

WHAT CALIFORNIA IS DOING FOR THE CONTROL OF INJURIOUS INSECTS

GERTRUDE BACON, UNIVERSITY OF ILLINOIS

California has been the pioneer in many matters pertaining to horticulture. The work as now carried on is under the direction of a horticulture commissioner, a skilled horticulturist and entomologist appointed by the Governor. He has a deputy commissioner and secretary to assist him. In practically all counties there is a county board of horticulture consisting of three members. To carry on the work more thoroughly the board divides the county into districts and appoints a local inspector for each district who has full authority to cause the inspection of any orchard, nursery, packing house, trees or plants. If any are found infested by injurious insects, the inspector must notify the owner and the owner is required to eradicate or destroy them within a certain specified time. If he fails to do this the county board does it at the expense of the county and attaches lien to the property.

The State has two aims in its work, to eradicate the injurious insects already in the State, and prevent all others from entering. To accomplish the first of these the State is trying by means of farm advisers, correspondence instruction, and monthly bulletins to spread the knowledge of the injurious insects and method of their control among the ranchers and growers. For the State must have their interest and co-operation to obtain the best results.

Artificial means of fighting insects by spraying and fumigation have proved so costly and insufficient that it is the work of the State to discover, introduce and establish new parasites to prey upon the injurious insects. It was in California that the natural parasites were first used to combat the insect enemies, and so thorough has been this work along all lines that there are today few serious pests for which there is not an effective enemy. Expert entomologists are kept in the field in California, in other states, and countries, who collect these parasites. They are forwarded to the State Insectary where they are supplied with the proper hosts and reared in sufficient numbers to be sent out into the sections of the State where the destructive insects upon which they prey are found.

As the most serious pests have been introduced species, it is important for the State to keep those from neighboring states and countries from entering. California has been a pioneer in affording a most complete system of protection to her main industry of agriculture, by means of quarantine,

and it was first in California that we find the word quarantine as applied to strictly horticultural material. Express shipments are as vigilantly inspected as those of freight and steamer. In spite of the strict quarantine laws and the efficient service, there still exists an open door by which injurious insects may enter and that is through the mail. This is especially true since the establishment of the parcel post and this door can only be closed by action on the part of congress, whereby the present law requiring the immediate delivery of mail will be abolished and making it mandatory that all packages of fruit and nursery stock be sent to two or three designated post offices for inspection and if found free of injurious insects to be then forwarded to the purchasers. It is toward obtaining such a law that the government is now working.

THE LABIUM OF THE NYMPHS OF ZYGOPTERA

PHILIP GARMAN, UNIVERSITY OF ILLINOIS

Several forms of labia occur in the Zygoptera, differing mainly as regards shape of mentum, submentum and lateral arms. There are also variations in the number of setae possessed by the different parts.

The labium can be homologized throughout with that of other insects. Palpi, ligula, mentum and submentum are present.

The use of the labium for capturing prey has led to rather extensive muscular development within. Two pairs of mental muscles serve to operate the organ to open and close the lateral arm. Two pairs of submental muscles, together with a pair of oblique basal muscles, open and close, extend and retract the piece as a whole. The presence of a median unpaired chitinous "rod" or ligament aids in this last operation, and is of interest because it occurs only in the Order Odonata . Caudad it is attached to the dorsal, ental surface of the submentum not far behind the articulation of that portion with the head capsule. Cephalad it is fastened to the cuticle immediately behind the hypopharynx.

THE COMPARATIVE MORPHOLOGY OF SOME CARABID LARVAE

C. C. HAMILTON, UNIVERSITY OF ILLINOIS

Carabid larvae have been studied but little in America, and it is generally believed that they do not possess distinguishing characters. A morphological study, however, shows distinct structural differences. These differences are found in the comparative length, size, and shape of the segments of corresponding structures. The number and arrangement of the setae upon the various appendages and sclerites of the body show distinct differences among the different species of larvae. The antennae, mandibles, maxillae and labium are well supplied with distinctive characters. The front and clypeus also shows considerable variation in its comparative length and width, the nature of its cephalic margin, and the number and arrangement of the setae.

SOME ADAPTATIONS FOR RESPIRATION IN AQUATIC HEMIPTERA

ABSTRACT

ANNA GRACE NEWELL, UNIVERSITY OF ILLINOIS

In Benacus griseus, the "giant water bug," or the "electric light bug," there is a pair of "strap-like appendages" projecting from under the wings, at the posterior end of the abdomen, in both male and female. Their morphology and function have not been exactly stated.

On soaking specimens in caustic potash, these appendages are found to be projections from and parts of the tergites of the 8th segment. Similar organs are present in Belostoma fluminea say (Zaitha), and very short ones in Notonecta. Both are the same, morphologically, as the ones in Benacus.

There is a large spiracle at the base not only of each projection, but also of a groove extending from the spiracle to the tip of the "strap-like" portion of the tergite. This groove is edged on both sides with a row of long, closely-set setae. Records of observations* as to methods of breathing in Zaitha

*Bueno, J. R. de la Torre: Life Histories of North American Water Bugs.
I. Life History of Belostoma fluminea Say. Can. Ent. 1906; v. 37, 1906, pp. 189-197
II. Life History of Ranatra quadridentata Stal. Can. Ent. v. 38, 1906, pp. 242-252.

and other aquatic hemiptera by Mr. J. R. de la Torre Bueno, lead one to feel confident that the organs described above, in Benacus, and Notonecta, as well, are respiratory in function.

(Paper illustrated by lantern slide, showing structures mentioned.)

A MORPHOLOGICAL STUDY OF THE HEAD AND MOUTH-PARTS OF THE BLOW-FLY

ABSTRACT

ALVAH PETERSON, UNIVERSITY OF ILLINOIS

In order to reach a correct interpretation of the head and mouth-parts of the highly specialized Muscidae it is necessary to study the more generalized Diptera. At present such a study is being made. So far I have been able to secure representatives of thirty-eight families out of sixty-one listed by Williston. As a result of the observations on the forms thus far studied, a number of interesting relationships with respect to the mouth-parts have been worked out. When all the observations which I propose to make have been recorded, I feel quite sure that a number of the different points in the interpretation of the mouth-parts of the higher Muscidae (Blow-fly) will be made clear.

PUPAE OF THE LEPIDOPTEROUS FAMILY SPHINGIDAE

EDNA MOSHER, UNIVERSITY OF ILLINOIS

The pupae of the family in Sphingidae belong to the so-called obtect type of pupa in which the appendages are firmly soldered to each other and to the body.

They retain, however, one very primitive character, the presence of a portion of the first femur between the maxillae and the remaining portions of the first leg.

By far the most interesting thing about these pupae is the way in which they provide for the very long maxillae which are present in most of the sub-families. The body is strongly curved on the ventral surface, and the labrum is found on the dorsal surface of the head in many instances, thus allowing for considerable extra length. Others have a prominent

convexity at the proximal end of the maxilla where it is curved away from the remainder of the appendages. In one sub-family to which our common tomato worm, *Protoparce sexta,* belongs, the extra length is taken up in a sort of loop at the proximal end of the maxillae. This loop is closely appressed to the surface of the body, or prominently arched and touching only at its tip, forming the "jug-handled" type of pupa belonging to the above-mentioned species.

CONSTITUTION AND BY-LAWS

Illinois Academy of Science

CONSTITUTION

ARTICLE I. NAME

This Society shall be known as THE ILLINOIS ACADEMY OF SCIENCE.

ARTICLE II. OBJECTS

The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the scientific interests of the State.

ARTICLE III. MEMBERS

The membership of the Academy shall consist of *Active Members, Non-resident Members, Corresponding Members, Life Members and Honorary Members.*

Active Members shall be persons who are interested in scientific work and are residents of the State of Illinois. Each active member shall pay an initiation fee of one dollar and an annual assessment of one dollar.

Non-resident Members shall be persons who have been members of the Academy but have removed from the State. Their duties and privileges shall be the same as those of active members except that they may not hold office.

Corresponding Members shall be such persons actively engaged in scientific research as shall be chosen by the Academy, their duties and privileges to be the same as those of active members, except that they may not hold office and shall be free from all dues.

Life Members shall be active or non-resident members who have paid fees to the amount of twenty dollars. They shall be free from further annual dues.

Honorary Members shall be persons who have rendered distinguished service to science and who are not residents of the State of Illinois. The number shall not exceed twenty at one time. They shall be free from all dues.

For election to any class of membership the candidate's name must be proposed by two members, be approved by a majority of the committee on membership, and receive the assent of three-fourths of the members voting.

All workers in science present at the organization meeting who sign the constitution, upon payment of their initiation fee and their annual dues for 1908 become charter members.

Article IV. Officers

The officers of the Academy shall consist of a President, a Vice-President, a Chairman of each section that may be organized, a Secretary, and a Treasurer. These officers shall be chosen by ballot on recommendation of a nominating committee, at an annual meeting, and shall hold office for one year or until their successors qualify.

They shall perform the duties usually pertaining to their respective offices.

It shall be one of the duties of the President to prepare an address which shall be delivered before the Academy at the annual meeting at which his term of office expires.

The Secretary shall have charge of all the books, collections, and material property belonging to the Academy.

Article V. Council

The Council shall consist of the President, Vice-President, Chairman of each section, Secretary, Treasurer, and the president of the preceding year. To the Council shall be entrusted the management of the affairs of the Academy during the intervals between regular meetings.

Article VI. Standing Committees

The Standing Committees of the Academy shall be a Committee on Publication and a Committee on Membership.

The Committee on Publication shall consist of the President, the Secretary, and a third member chosen annually by the Academy.

The Committee on Membership shall consist of five members chosen annually by the Academy.

Article VII. Meetings

The regular meetings of the Academy shall be held at such time and place as the Council may designate. Special meetings may be called by the Council and shall be called upon written request of twenty members.

Article VIII. Publication

The regular publications of the Academy shall include the transactions of the Academy and such papers as are deemed suitable by the Committee on Publication.

All members shall receive gratis the current issues of the Academy.

Article IX. Affiliation

The Academy may enter into such relations of affiliation with other organizations of appropriate character as may be recommended by the Council and be ordered by a three-fourths vote of the members present at any regular meeting.

Article X. Amendments

This constitution may be amended by a three-fourths vote of the members present at an annual meeting, provided that notice of the desired change has been sent by the Secretary to all members at least twenty days before such meeting.

BY-LAWS

I. The following shall be the regular order of business:

1. Call to order.
2. Reports of officers.
3. Reports of standing committees.
4. Election of members.
5. Reports of special committees.
6. Appointment of special committees.
7. Unfinished business.
8. New business.
9. Election of officers.
10. Program.

Adjournment.

II. No meeting of the Academy shall be held without thirty days' previous notice being sent by the Secretary to all members.

III. Fifteen members shall constitute a quorum of the Academy. A majority of the Council shall constitute a quorum of the Council.

IV. No bill against the Academy shall be paid without an order signed by the President and Secretary.

V. Members who shall allow their dues to remain unpaid for three years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

VI. The Secretary shall have charge of the distribution, sale, and exchange of the published transactions of the Academy, under such restrictions as may be imposed by the Council.

VII. The presiding officer shall at each annual meeting appoint a committee of three who shall examine and report in writing upon the account of the Treasurer.

VIII. No paper shall be entitled to a place on the program unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary.

IX. These by-laws may be suspended by a three-fourths vote of the members present at any regular meeting.

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(Revised May, 1915.)

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